Birbal Sahni

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ACKNOWLEDGEMENTS

To write about men who have been pace-setters and path-finders in their lives is no easy task. Professor Birbal Sahni was such a man.

To write this biography, I have drawn extensively from the childhood reminiscences of Mrs Lakshwanti Malhotra (Dr Sahni's sister) and Mrs Savitri Sahni (Dr Sahni's wife) whose life's mission has been to sustain and carry out the work that Professor Sahni's premature death could not let him complete. The latter was gracious enough to lend me writings in her possession which I have drawn upon, and spared many precious hours to talk to me.

I am also grateful to my brothers, Dr Prahlad Dev Malhotra and Lt.-Col. Arvind Dev Malhotra whose help in gathering the material for this biography was invaluable. Dr R.N. Lakhanpal of the Birbal Sahni Institute of Palaeobotany, Lucknow, was good enough to go through the script and made many suggestions which were of immense help

I have drawn extensively from Professor Birbal Sahni's numerous research papers as well as from the tributes that men of letters paid to this colossus among men, when death's cold hands put an abrupt end to his brilliant career.

The Institute of Palaeobotany at Lucknow is a standing memorial to his contribution to science. Had death

spared him for a few more years, Palaeobotany and the world of science would have been richer but then, as a poet said: "The good die first and they whose hearts are dry as summer's dust burn to the socket."

SHAKTI M. GUPTA

New Delhi
1978

To

Mrs Savitri Sahni
for her courage

I

The Palaeobotanist

On the midnight of April 10, 1949, the Divine Call came for Professor Birbal Sahni. The call came when Professor Sahni was at the height of his professional career and his name was, as one of the foremost palaeobotanists of the world, known far and wide.

In September 1948, Professor Birbal Sahni returned to India after his lecture tour of the United States of America. The foundation of the building for the Institute of Palaeobotany, at Lucknow, was to be laid. Fulfilment of his most cherished dream was in sight but he looked tired. He was advised complete rest and was recommended a trip to Almorah for recuperation before he plunged into the work scheduled ahead. But Professor Sahni was adamant on staying on in Lucknow and first completing the job, almost as if he had a premonition of his death. It was this overwork and anxiety that brought on an attack of coronary thrombosis which proved fatal. The sad day was exactly a week after the foundation-stone of the building of the Institute of Palaeobotany was laid by the then Prime Minister, Pandit Jawaharlal Nehru, who also happened to be a personal friend of his.

On April 3, 1949, amidst a distinguished gathering, the foundation-stone of the Institute was laid at 53 University Road, Lucknow. The foundation-stone, three feet by two feet in size, was a mosaic formed by embedding in it

seventy-seven rare fossil specimens from all over the world, and was set at his residence under his own supervision. It was a strange coincidence that Pandit Nehru had also studied Botany and Geology at Cambridge, was a near contemporary of Professor Sahni, and both were born on November 14.

It is an irony of fate that the very spot from where Professor Sahni, only a week earlier, had stood to give his inaugural speech, was later to be his final resting place. His mortal remains were consigned to the sacred fire at that very spot, watched by his weeping relatives, friends, students and colleagues. His restless spirit, which for over thirty years had toiled feverishly and had given the world of science a new perspective of Palaeobotany, was at last laid to rest.

The last ten years of his life were devoted to the establishment of an institute of palaeobotany at Lucknow. As early as 1939, a committee of senior palaeobotanists was set up to co-ordinate the research work done and to issue periodic reports. On May 19, 1946, the 'Palaeobotanical Society' was formed, and a trust was created for the foundation of 'A research institute having a broad international outlook, comprising a museum, a library, a laboratory, residential quarters and auxiliary buildings.' A Governing Body was set up with Professor Sahni as its Honorary Director. Funds started pouring in from all over. The Imperial Chemical Industries and Burmah Shell provided two Research Fellowships.

The Palaeobotanical Institute that Dr Sahni had toiled so hard to bring to life was a lifetime mission for him and he had conceived the idea of starting such an institute in the mid-thirties. But even though he sowed the seeds of the Institute, he was not destined to see it flower. The task of putting the Institute on a sound footing and

making it recognized internationally was left to his wife, Mrs Savitri Sahni. She has done a commendable job. The Institute, what it is today, owes a lot to her courage against heavy odds. Professor Sahni's last words were addressed to her, "Nourish the Institute."

II

Family Background

PROFESSOR Birbal Sahni was the third child of Professor Ruchi Ram Sahni and Shrimati Iswar Devi He was born on November 14, 1891, at Bhera, a small trading town in the Shahpur District of West Punjab (now in Pakistan), where the family had migrated from Dera Ismail Khan in the North-West Frontier Province of the erstwhile State of Punjab before 1947. The fact that he was born at Bhera was not an accident. The author understands from her mother, Mrs Lakshwanti Malhotra, the youngest sister of Professor Birbal Sahni, that their mother, Shrimati Iswar Devi, believed that all auspicious ceremonies and important events concerning the family ought to take place in their family house and went to Bhera from Lahore, every time a child was expected. The birth of Birbal Sahni was considered an auspicious event as a slight rainfall occurred at the time of his birth, which is considered highly auspicious by the Hindus.

The family often visited Bhera during the school and college vacations and, from there, young Birbal, in the company of his father and brothers, made treks to the surrounding countryside, which included the nearby Salt Range, particularly at Khewra. Maybe it was then, that his interest in Geology and Palaeobotany was aroused, because the Salt Range had plant-bearing formations and was a veritable museum of geology. In later years, Professor Sahni was to make important contributions towards

ascertaining the geological age of this area.

Professor Sahni was not just a scientist and a scholar, but also a great patriot, and a deeply religious man, though he never discussed his religious views. He was a man of sterling qualities, generous and self-sacrificing He imbibed these qualities from his father who himself was an embodiment of all these virtues Professor Ruchi Ram Sahni was a profound scholar, and a pioneer in social reform, particularly in the field of emancipation of women.

The family originally belonged to Dera Ismail Khan which was an important trading town on the banks of the river Indus Professor Ruchi Ram Sahni had to leave the city at a very young age due to reverses in the family fortune and the death of his father who at one time had a flourishing banking business While yet at school, the author learnt of the family history from her grandfather, Professor Ruchi Ram Sahni, during summer holidays spent with him at Gulmarg in Kashmir. From the stories narrated, one can gather of what stern stuff Professor Ruchi Ram Sahni was made and no doubt this affected his son Birbal as well. One particular anecdote is worth recording. After the family moved from their palatial mansion at Dera Ismail Khan to a small house, and all luxuries had to be given up, Ruchi Ram Sahni went to his father and complained that his playmates teased him as he no longer wore a silk shirt or gold ear-rings and bangles, the hallmark of affluent people those days. His father answered: "Black clouds have spread all around. Let them pour as hard as they can. They can only wet the clothes, but cannot dampen the spirit within. The clouds will disperse one day."

But this was easier said than done. Ruchi Ram Sahni was still a child when his father died a broken man After that it was not possible to continue to live in Dera Ismail

Khan where once the family held prestige and fortune. However, Ruchi Ram Sahni was not to be deterred by this initial setback in the fortunes of the family. Determined to acquire education at any cost, he walked with his bundle of books one hundred and fifty miles away to Jhang (a town in West Punjab, now in Pakistan). He was educated entirely on scholarships. Being an intelligent and a promising lad, scholarships were not difficult to find but the early years were beset with great hardships. An interesting anecdote that he told the author regarding his trip to Jhang was that he reached a small halting place as night was falling. He had with him his bundle of books and a sum of rupee one and paisa twenty-five only, which to a poor child was almost a fortune. There was no question of his spending the night at an inn. The choice before him was to spend the night in a stable or else climb up a tree and sleep there. In the stables, he was afraid his books, his most precious possessions, might be stolen. So he climbed a tree but dared not close his eyes lest he fell down. From such hard days of his life as a student, he rose to be the Professor of Chemistry at Government College, Lahore. Lahore, by then, had become the family home for all practical purposes and Bhera was relegated to the background though the family was still called Bharuchi, i e. residents of Bhera.

Professor Ruchi Ram Sahni sent his five sons for higher studies to England and also went there himself. He went to Manchester where he carried out investigations on radio-activity with Professors Ernest Rutherford of Cambridge and Neilsborne of Copenhagen. He was in Germany when the First World War started and managed to cross the border to safety a day before the start of hostilities. It was in fact his initiative and inspiration, encouragement and steadfastness, hard work and integrity,

which to a great extent inculcated an attitude of scientific enquiry and moulded the character of his son Birbal and this is borne out by the fact that Professor Birbal Sahni never accepted defeat in his research work and, no matter how hard the problem, he was always ready to tackle it. It was an attitude of taking life as a big challenge that became the motto of the family.

Professor Birbal Sahni was a staunch supporter of the Freedom struggle and this may again be due to the influence of his father, who, in 1922 during the days of the Non-co-operation Movement, returned the title conferred on him by the British Government as a protest against the massacre at the Jallianwala Bagh in Amritsar in spite of the fact that he was threatened with the termination of his pension. Ruchi Ram Sahni replied that he was prepared for the consequences. But such was the force of his personality and popularity that the British Government dared not touch his pension and he retained it till the very end.

Those were turbulent days. The Freedom struggle was at its height. All patriotic-minded people were contributing in some way or the other towards the country's goal of attaining complete independence. At such crucial times, the presence of political figures like Motilal Nehru, Gokhale, C. R. Das, Srinivasa Shastri, Sarojini Naidu, Madan Mohan Malaviya, Hakim Ajmal Khan and others, who were guests at their house in Lahore, also contributed to his political affiliations. The proximity of their house to Bradlaugh Hall was also to influence his political leanings. Bradlaugh Hall was the centre of political activity in Punjab. One heard, almost daily, about the arrests of political leaders, political meetings, tear-gas bombs, lathi-charges on innocents, and indiscriminate arrests. All this could not but have left an impression on the sensitive mind of young Birbal. Birbal Sahni, soon after returning

to India in 1918, after completing his studies abroad, gave a practical twist to his political feelings and started wearing hand-spun, Khadi.

Birbal Sahni was a man of very deep attachments which perhaps he imbibed from his self-sacrificing mother, who, though an orthodox, unassuming woman, was a typical Punjabi woman, strong and brave at heart, and steered the family through many a crisis. In spite of a strong opposition from orthodox friends and relatives and her own conservativeness, she agreed with her husband to send her daughters for higher education which by itself was a very great revolutionary step to take in the early years of the present century. In fact, she strove to give all her children a sound education which stood them in good stead in later life. The third daughter of Professor Ruchi Ram Sahni, Mrs Leela Kohli, had the honour of being the first woman to graduate from the Punjab University, Lahore. In spite of the fact that she did not believe in late marriages for the daughters, early marriage being the tradition those days, Shrimati Iswar Devi respected her husband's wishes and did not insist that the daughters of the family marry young.

While still a child, Birbal had gained the reputation of having a very humane attitude towards life. He was invariably chosen as the arbitrator in disputes amongst his sisters and brothers, for he was known to be fair-minded. Lest one gets away with the impression that he was a serious-minded young man, I would like to emphasise that he was known for practical jokes and often led his younger brothers and sisters to mischief which sometimes caused great embarrassment to his father. This bent for mischief took various forms. Once the family had gone to Simla during the summer months for a holiday. There, they were sharing a house and a garden with friends of the family.

In the vegetable garden they grew corn and cucumbers. For some reasons, Birbal's family had to suddenly return to Lahore. This meant that the vegetable garden with its cucumbers had to be left for the neighbours to enjoy. This was too much for the mischievous young Birbal to take. He conceived a plan to remove all the ripe fruits at night before their departure and then to cut the roots of the plants at the very base so that mischief would not be detected. The plans were duly carried out by his brothers and sisters, resulting in the plants dying off soon after. The neighbours were at a loss to know as to what was the cause and in spite of watering and giving manure, the plants did not survive. They did not find out the mischief done till much later when they returned to Lahore at the end of their vacation and found out the trick played on them.

Even in later life, Birbal Sahni was always cracking practical jokes on his young nieces and nephews, or telling jokes and anecdotes to his students while on botanical tours. He was nicknamed *Tamashewala uncle* by his nieces and nephews. His pet joke was to play with a gloved monkey toy that he had bought in Germany in 1913 when he was attending the summer semester, the botany lectures of Professor Goebel at Munich. The gloved monkey would be so held by him that unless one was aware that it was only a toy, one could easily mistake it for a baby monkey that he was caressing This gloved monkey was not only a delight of all children, but also in a way responsible in breaking the awkwardness between him and his wife. When Professor Sahni got married and was with his wife for the first time, to break the awkward silence and embarrassment between him and his young bride, he showed her just the face of the monkey, peeping out of his coat pocket and said: "This is my pet monkey of whom I am very fond of. So far I have alone looked after him. But from today onwards,

I want you to take care of him." He then asked her to caress the monkey who, he said, needed love and affection. His wife did not know that it was only a toy and hesitated to touch it. When she came nearer to the monkey and realised that it was only a toy and it was a joke that he had played on her, they both burst into laughter and thus the awkwardness between them disappeared.

Professor Sahni's association with his pet monkey glove was so great that it was difficult to disassociate him from it. The monkey with its sad, human expression was a lucky mascot and travelled with him everywhere, even to distant lands by sea, land and air. There was not a country which Professor Sahni visited without the pet monkey glove accompanying him, nor a trek for fossil hunting or for pleasure. This toy monkey, christened Gippy by him, after his master's death, is now lying with other precious belongings of Professor Sahni, waiting to be displayed in his room at the Institute of Palaeobotany.

Birbal Sahni was brought up in an atmosphere of liberal views. His father had gone to Calcutta to do a Master's course in Chemistry as the Punjab University did not have necessary facilities for it at that time. This was a time when the Brahmo Samaj movement was very strong there. He attended the lectures of Keshab Chandra Sen, and was greatly impressed by the tenets of the Brahmo Samaj. He returned to Lahore a staunch supporter of the new progressive group. Brahmo Samaj was a social and religious upsurge breaking away from many old traditions which had lost their meaning in the changed times. Its one great progressive trend was to break away from caste. Professor Ruchi Ram Sahni, who was a leader of the Brahmo Samaj group in Lahore, gave it practical effect by getting his eldest child, Dr. Bikrama Jit Sahni, married out of caste and challenged his community to ostracize him if they dared.

No one had the courage to do so, though there were many who voiced their disapproval. In his house at Lahore, there was no bar to caste, creed or religion and members of all religious communities were constant visitors. Political, religious and academic discussions used openly to take place. When the Arya Samaj, a socio-religious, political and educational reform movement, started in Punjab, Professor Ruchi Ram Sahni was one of the leading members of the Lahore intelligentsia who voiced their views on the subject Birbal Sahni was brought up in this atmosphere, where even though obedience to elders was expected, the views of the young were respected. This is clear from the words of Dr M. R. Sahni, his younger brother, "Father had planned the Indian Civil Service as a career for him . . . . . Birbal was asked to prepare for his departure. There could not be much argument about it, but I distinctly remember Birbal's answer that if it was an order, he would go but if his own inclinations in the matter were to be considered, he would take up a research career in Botany and nothing else. Although this astonished father for a while, he readily consented, for in spite of his strong disciplinarian attitude, he gave perfect freedom of choice in essential matters. Father was one of those disciplinarians from whom a mere suggestion was usually enough to settle where the decision lay."

It was in such an atmosphere of obedience to elders and at the same time with the right to think and act according to one's own judgement, in an atmosphere of constant rebellion against the alien rule, and in an atmosphere of higher learning, that Birbal Sahni passed his early years.

III

School and College Education

SAHNI's early education was entirely in India. After completing his studies at school, he joined the Government College, Lahore and studied Botany under Professor Shiv Ram Kashyap, the famous Bryologist, who inspired him to take Botany as his main career. Birbal showed his love of plants at a very young age The family had got used to his habit of collecting plants to make a herbarium, or to preserve them in bottles for further study. While a student at Government College, Sahni was in the habit of roaming around in the open space beyond their house, outside the city walls and in the vicinity of Bradlaugh Hall. Often he would uproot a plant that was new to him and bring it home to plant it in the garden. On one such occasion, he came across a sapling of the Indian Laburnum (*Cassia fistula*) popularly called *Amaltas* or the Golden Shower. The name Golden Shower is given because the round, golden yellow petals fallen on the ground below the tree give the impression from a distance as if gold coins are strewn there. Birbal got excited by his discovery and ran home breathless with excitement. Followed by his younger sisters and brothers, the whole horde of children reached the spot where the sapling was growing. It was dug up and planted in their garden. A few years later when the sapling became a tree and started bearing panicles of yellow flowers, there was no end to the joy in the family. The relations coming from

their far off village on a visit, invariably collected the fruits of the tree for medicinal purposes and blessed young Birbal for it. The tree was still there when the family moved from Lahore after the 1947 holocaust following the partition of the country. But by now, Birbal Sahni's love for the Indian Laburnum tree had become almost a legend. When he built his house on the banks of the river Gomati in Lucknow, he planted the tree on both sides of the road. The tree with its hanging panicles of yellow flowers against the hot summer sky, reflecting in the waters of the Gomati, was a breath-taking sight and commented upon by most visitors to the city.

Birbal Sahni took his degree of Bachelor of Science from the University of Punjab in 1911, and the same year he proceeded to England and joined Emmanuel College, Cambridge He graduated from Cambridge in 1914 and straight away settled down to serious research under the inspiring guidance of Professor A C. Seward who was the most distinguished botanist of the time. In 1919, Birbal Sahni was awarded the degree of Doctor of Science (D Sc.) by the London University for his researches on fossil plants. His love for botany and his knowledge of the living plants of India was so great that when he was still a student, he was asked to revise Lawson's textbook of botany, to suit the requirements of students of botany in India. The Textbook of Botany by Lawson and Sahni is still a widely read book on the subject, both in colleges and universities of India. For this stupendous effort, Birbal Sahni was given a paltry sum of £20.00 and no share in the royalty. Worse than that, an undertaking was taken from him which bound him for life, not to write another textbook of Botany, which might hamper the sale of this book.

IV

His Travels

PROFESSOR Sahni was a very well travelled man, not only in India but had made several trips to various countries all over the world. In India his one great passion was trekking across the length and breadth of the Himalayas, a love he inherited from his father, who was himself very keen on trekking and took his children with him even when they were quite young, on various trips into the mountains. Among the many trips that Birbal made as a young man were treks from Pathankot to Rohtang Pass (12,000 ft. high); Kalka to the borders of Tibet via Kasuali, Sabathu, Simla, Narkanda, Rampur Bushar, Kilba and Buran Pass (16,800 ft. high); Srinagar to Dras across the Zoji la Pass; Srinagar to Amarnath (14,000 ft); Simla to Rohtang Pass and treks to many other places. He had travelled as far as the borders of Tibet. During the summer of 1911, just before his departure for England, on a trek to Machoi Glacier, not far from the Zoji la Pass, Birbal collected a rare red alga in the snow. He took this specimen with him to England and it was examined by Professor Seward at the Botany School, Cambridge. It was on this very trip to Machoi Glacier, when looking down a chasm, he saw a horse frozen to death, still standing, preserved in his icy grave. Equipped only with hand-made rope chappals traditionally worn by the local people because of their low cost and also for their ability to prevent the foot from slipping on the snow, and accompanied by a local guide and his brothers, he

suddenly realised that one false step and they would meet the same fate as the horse.

His trips to the various countries outside India, apart from his student days, were either on a lecture-tour, or to take part in a seminar or to visit universities and institutions, or to head some scientific committee. After his marriage, Mrs Sahni invariably accompanied him on his treks and trips. One such trek was memorable for them. They were trekking from Srinagar via Uri, Poonch to Chor Panjal, Pal Gagrian and then to Gulmarg. His love of adventure often proved hazardous when he explored new places, and this was one such trek where the party had a narrow escape. Accompanied by Mrs Sahni and a small party of porters, he camped at a great height. As evening fell, the snow started falling. It was such a heavy snowfall that there was a danger of everyone getting lost. Professor Sahni asked the sure-footed, hardy coolies to try and get away to safety while there was yet time and prepared to face a snow-covered grave with his wife. It was a difficult night to pass in the bitter cold with everything frozen. Luckily for them, one of the coolies having reached safety, informed others of the Professor and his beautiful wife being trapped in the snow. Professor Sahni had hired coolies for the trek from the same village and the village Headman had personally supervised the hiring of the coolies. When informed of the fate of the couple, he arranged a rescue party. In the morning, when Professor Sahni saw with his binoculars a rescue party coming towards them, he could hardly believe it. Luckily for them, the men who came to take them to safety were hefty, strong men and knew their way around. By then, the snow was almost knee-deep.

Not many are aware of Professor Sahni's deep interest in the arts. He was very fond of music and could play the

sitar and the violin. His one great hobby was drawing and clay-modelling and, whenever time permitted, he loved a game of chess. From a very early age, he was fond of games and retained this interest in sports till late in life. At school and college, he was keen on hockey and tennis and also represented these institutions in the hockey XIs. Even at Cambridge he represented the Indian Majlis at tennis and played against the Oxford Majlis.

Professor Sahni was basically a palaeobotanist and a geologist. But he also had a very wide range of interests in various other subjects, for instance, in archaeology and numismatics.

V

Palaeobotany

PALAEOBOTANY is the science dealing with plants of the geologic past and is based on plant fossils or the remains of plants preserved in rocks. They are usually found as leaves, seeds, twigs, spores, flowers, fruits or as pieces of wood, but seldom an entire fossilized plant is found intact. From the fossil records it is possible to ascertain the age of a rock as a given sedimentary layer or formation contains a certain characteristic type of life only. There has been a progressive complexity of plant and animal structure through the ages. This is clearly borne out by the fossil records in different layers of the earth. Thus a general determination of the age of a rock by using fossils as indicators is based upon the presence or absence of certain major groups of plants or animals. These fossils record the presence of aquatic plants upon the earth as far back as the Proterozoic era about 15,000,000,000 years ago. Land plants are known first from Silurian rocks laid down during the Palaeozoic era. The evolutionary development of plants from small, simple organisms to the modern angiospermic trees, with their high level of structure, development and organisation, is closely related to the Science of Botany. This stratigraphical occurrence of plant fossils falls in the field of geology and if one can associate the time of appearance, dominance and extinction of a particular flora with rocks of known age, it is possible then for geologists to correlate

other rocks containing the same type of vegetation to the age of the rocks. Fossil plants also supply the geologists with a fairly reliable evidence regarding ancient climates and topography. Then by comparing the temperature and moisture requirements of related living forms to those of fossil plants, the geologist can with a fair accuracy correlate the conditions of plants of the geologic past as the two must have lived under similar environment. Thus both the geologists and botanists hold that plant fossils can indicate not only the time when a particular type of a plant lived and flourished or the nature of the land they must have occupied, but also the evolutionary lines on which the plants developed from the most simple to the most complex, as well as the relationship of the principal group of plants. By studying the fossil records and the geologic age of the earth, it has been found that there is no trace of woody plants till the beginning of the Silurian period, i.e. 325 million years ago. Gymnosperms and wingless insects appear in the Devonian period, roughly 316 million years ago. The first winged insect is recorded from the Upper Carboniferous rocks 230 million years ago and the familiar modern plants, the angiosperms, are the most advanced types and the rock formations containing them are Cretaceous or younger. The fauna and the flora of the earth first seem to have begun to wear their modern aspect at this time, about 60-70 million years ago. Also that the more primitive plants, the pteridosperms, became extinct during the Jurassic. The pteridosperms of the Carboniferous period are among the most valuable indicators for they evolved rapidly and lived for only a short segment of geologic time before they became extinct. Another reason for these fossils to have been good indicators is because some of their species grew abundantly and were distributed

over a vast geographical area. Therefore, if index fossils are present in rocks of unknown age, then fitting together certain geologic criteria, it is possible to correlate the age of these rocks to those rocks where the age is well known.

Professor Sahni explained this in simple language: "We can tell the strata one from the other much more surely by their contained fossil remains. Imagine, for example, that in a coal mine on a certain day, a person had been sitting by the trough eating grapes and throwing the seeds into the water, then we could easily tell the day of the week by the grape seeds in the particular layer of chalk that was then being laid down. Or if, during a certain night, there were swarms of insects round a light in the mine, and some of the insects, falling into the trough or washed into it by the streams, were buried in the chalky silt then being formed, we could exactly date, and even time, the layer by its contained insect remains."

VI

Early Career

PROFESSOR Sahni returned to India in 1919 after completing his studies at Cambridge and was appointed Professor of Botany at Banaras Hindu University. After teaching there for one year, he moved to Lahore and taught Botany at the Punjab University from 1920 to 1921. In 1921, Dr. Sahni was appointed Professor of Botany at the University of Lucknow. He continued to head the department of Botany and later of Geology also, till the time of his death in 1949.

One of the first things that Professor Sahni did after taking charge of the department of Botany was to revise the course of studies of the under-graduate classes and to organise the teaching of Honours and post-graduate classes. In spite of his heavy schedule, he insisted on taking the B.Sc. classes himself, as he believed that the junior classes should be handled to a certain extent by the senior teachers so as to instil better discipline among the students. It also provided a balanced and methodical tuition and gave inspiration and correct guidance to the young impressionable minds. His great personal interest in the students made him an object of adoration. He would personally check the drawings of the students or explain a difficult point without ever losing his temper. He always praised the hard-working diligent students and rebuked, but casually, the idle students which only made the unwilling students work more briskly.

Once, due to unavoidable circumstances, Professor Sahni discontinued taking under-graduate classes. The students were very upset by his decision and approached Mrs Sahni and requested her to speak on their behalf to Professor Sahni. The result was as expected. Professor Sahni resumed taking under-graduate classes.

The international reputation or the honours showered on him at an early age did not, as might be expected, make him arrogant. On the contrary, his pleasant nature, humility and helpfulness continued unabated and the students did not hesitate to approach him whenever they were in need of advice and guidance. Mr R.S.C. Pal of the Geological Survey of India recalls the following incident that took place while he was a student at the Lucknow University. The first vacations after he had joined the university came Mr Pal was leaving for his home town. But no public transport was available and the time for the train's departure was drawing ominously near. He started walking on the university road hoping to find some mode of transport that would take him to the railway station. Just then a car stopped and the driver of the car asked him the cause of his again and again turning his head backwards, and if he could be of any help. Young Pal told him the cause of his getting into a panic. The driver of the car asked him to hop in and took him to the railway station in time for him to catch his train. On getting down from the car, Pal asked him whom he was indebted to for this help. "My name is Birbal Sahni," came the answer, and the car drove off. Pal no doubt had heard the name and fame of Birbal Sahni but had never seen him before.

Mrs Sahni recalls the devastating floods of 1923 when vast areas of Lucknow were submerged by the swollen waters of the Gomati river overflowing its banks. It was

during the early days of Professor Sahni's career. Professor Sahni's house was quite close to the river and was not spared by the fury of the flooded river. The flood waters came gushing over in such a spate that it was impossible to salvage most of their furniture and other belongings. But luckily, Professor Sahni managed to remove his fossils and research papers to safety in time. There being a paucity of available accommodation, they had to share for a while a house with three other families who were in the same plight. Because of the acute shortage of accommodation, even the kitchen had to be shared and the women of these families took turns to supervise the kitchen. One day it was Mrs Sahni's turn to see that the lunch was ready on time. It was getting late but the fire in the makeshift kitchen would not burn. Mrs Sahni got impatient and asked the cook to shake the logs of wood so as to quicken the fire. He grumbled· "For the past one hour, I have shaken this log of wood, fanned it but it is so obstinate that it will not burn. I wonder what kind of a wood this is." Mrs Sahni answered impatiently, "Get aside. You can't even light a fire. Let me do it." But the minute she pulled out the 'wood', she saw that it was the fossil wood which Professor Sahni had retrieved with great difficulty from his house under flood waters and had brought it to safety in preference to his personal belongings and the cook had mistaken it for firewood. This fossil wood was Dicotyledonous of the Eocene period, probably from the Deccan Inter-trappean Series, about 60 million years ago.

According to his colleagues and students, Professor Sahni had a direct and very simple style of teaching. At first he would stress the obvious important facts and the broad outlines of the topic and then would fill in the details. He made the illustrations for his lectures simultaneously with both hands, as fast as he would talk and

without missing a detail. The most significant part of his teaching was that he never failed to mention the latest research done on the subject and its progress in India. Gifted with a phenomenal memory, he could easily quote from references and never had to consult his notes while teaching. According to his colleague, Dr A.R. Rao of the Geology Department of the Lucknow University, "His lectures, to whatever audience addressed, were characterised by a remarkably simple and lucid style, direct and accurate expressions and attention to detail. Correct accent, a perfect command of the language and a pleasant voice added to the charm of his lectures."

The fame of Professor Sahni's lectures drew students from all over India, seeking admission to his Botany classes. But it was Professor Sahni the researcher, who eclipsed Professor Sahni the teacher. Research was the dominating passion of his life and he expected the same devotion to research from his students as well. The hard work, accuracy and attention to detail that he emphasized were also expected from his students which developed a "sense of responsibility, self-confidence in the students and a love for accurate, methodical work". According to Dr Rao, "the illustrations that accompanied the research papers had to be meticulous and perfect".

Professor Sahni's great contribution to the life and status of the University of Lucknow was not that he presided over the departments of botany and geology, but that he raised these departments to be foremost centres of teaching and research in the country. But in spite of his best efforts, it was not till 1932 when the Government of the United Provinces (Uttar Pradesh) sanctioned a sum of Rs 4,000/- to enable him to purchase for the department a fossil cutting machine and other necessary accessories that made it possible for a larger turnout of work in a

much shorter time. Till then, he used personally to cut the fossils with a wire-bow.

Although the department of Botany at the University of Lucknow had been functioning for many years, the main attraction of the department was Palaeobotany. Professor Sahni had for a long time been feeling that without the necessary geological background, students of palaeobotany were seriously handicapped, as geology, a sister science, was not being taught there. With this in mind he worked hard for many years for starting the Department of Geology at the Lucknow University and finally succeeded in 1943, when this discipline was opened at the university. He was the Head of this department also, and himself taught physical and stratigraphical geology to the post-graduate students before they started their regular course on morphology. A special paper on Palaeobotany for M. Sc. students was started and only those students who had taken this paper were considered qualified for higher research in the subject.

Professor Sahni sought to solve the problems of one branch of science by the methods of another. In 1936, he wrote in *Current Science*. "In this age of specialisation, which inevitably tends to confine thought to compartments, one is apt to overlook or to underrate the bearing of one branch of science upon another."

He had a unique method of solving scientific problems. For instance, he studied the Theory of Continental Drift from the point of view of fossil plants, or he studied the cultivation of rice and other food grains as early as the Indus Valley Civilisation which provided the link between archaeology and botany. Sahni, during a trip to Harappa, an important town of the Indus Valley Civilisation (*c.* 2500 BC), discovered charcoal remains of a species of conifers which showed that the inhabitants of this pre-

historic city were trading with the people of the mountains from where the wood must have been imported as Harappa does not grow any conifers.

Similarly, in the mound at Khokra Kot near Rohtak, he found shapes of the husk of rice impressed in clay, which resembles the *Oryza sativa* variety *plena*, a kind which has more than one grain in each spikelet. He also recovered, by chemical treatment, cells and stomata from terracottas found there, an evidence that strongly suggested to him, that this variety of rice was grown by the Yaudheya tribes about two thousand years ago. Since he did considerable research on certain coin moulds found by him near Rohtak, he tried to find the etymological name of the city of Rohtak and found that the city had been named after a plant called *Rohitaka* (Latin *Amoora Rohituka* W. & A; synonym: *Andersonia Rohituka* R.) He mentions that with a reference to the published floras, however, shows that this plant does not occur anywhere in Punjab, in fact, nowhere in northern India, west of Oudh. It may be that it has become extinct in Punjab during historic times. *Amoora Rohituka* is a member of the family Meliaceae. It is a middle-sized evergreen tree with a heavy crown of foliage and with a bark which is used as an astringent. It is stated to occur over a wide area including Oudh and north-east India, the Western Ghats, Ceylon and Malaya.

In 1936, Sahni collected from the Karewa Series of the Himalayas, a few flakes which appear to be human artifacts. He showed by means of this evidence that the Himalayan uplift is younger than the appearance of man in India.

His interest in varied subjects points to the versatility of the man. He did not merely confine himself to the

subject of fossil botany but took interest in practically all allied subjects.

Professor Sahni considered research for research's sake more important than acquiring degrees and till 1932, he did not take any students under him for a doctoral thesis. It was in 1933 that for the first time a number of students enrolled under him for the Ph.D. degree and from then onwards, it was a continuous stream of students, all desirous of working with the great scientist. Between the years 1933 and 1949, sixteen students obtained their doctorates under him.

Although he himself was a palaeobotanist, he encouraged research in all branches of science. It was in fact due to his sympathetic encouragement that research in other botanical fields like Ecology, Mycology and Bryology also progressed in the department. And it was to encourage research that he instituted a research prize in the name of his father, Professor Ruchi Ram Sahni. The prize was constituted from the monthly allowances that he received as Dean of the Faculty of Science, and was awarded every year for the best piece of botanical research by a post-graduate student of the botany department. It was a rare privilege for Professor Birbal Sahni to have been unanimously elected the Dean of the Science Faculty in 1933 and to hold that position till his death in 1949.

VII

Contributions to Indian Numismatics

ON March 24, 1936, Professor Sahni visited Rohtak in response to an invitation from the Punjab University to deliver extension lectures on Botany. His attention was drawn by a friend, Dr V.S. Puri, to certain mounds at Khokra Kot in the immediate vicinity of the city. He discovered there a very large number of relics exposed at different levels in the crumbling sides of the ravines, cut by the rains. In the words of his brother Dr M.R Sahni. "This archaeological discovery by a Palaeobotanist, with the stroke of a geologist's hammer, symbolises the vitality and versatility of the man "

Whenever Professor Sahni undertook a job, he did it scientifically and diligently and this is borne out by his discovery at Khokra Kot. Not only did he discover the coin moulds but also made a detailed study of ancient Indian methods of casting coins. This led him to make a special study of the techniques of casting coins in other countries, particularly those adopted in China and during the Roman period in Europe and North Africa, and he compared those methods with the methods prevalent in India. From the vast data collected and studied by him, it was interesting to know that India, a hundred years before the Roman Era, had evolved a complex multiple mould of a type considerably more efficient than any yet discovered in Europe. This work was published in a monograph in the Journal of the Numismatic Society of

India in 1945. The title of the paper was: "Technique of casting coins in ancient India."

Professor Sahni immediately recognised the great value of his accidental discovery of some thousands of terracotta moulds with a few coins still lying within them. This discovery could be said to be the luckiest find in the history of Indian Numismatics. The discovery was announced by Professor Sahni in an article entitled: "Antiquities from the Khokra Kot Mound at Rohtak in the Jumna valley." This appeared in the May issue of *Current Science* in 1936. He prepared plasticine positives of the coin moulds which are datable to *c.* 100 B C. and asked Dr K. P. Jayaswal, the distinguished Indologist, to decipher the inscription on them. The inscription deciphered by Dr Jayaswal turned out to be, *Yaudheyānā (m) Bahudhāñayaka*, i.e. coins of the Yaudheyās of Bahudhañaka.

Quoting Dr V. S. Agarwala: "Although the coins of the Yaudheyas have been known for more than a century, we were for the first time face to face with one of their mint towns, precisely located in the suburbs of Rohtak, and what was more valuable still, the name of an important section of the Yaudheya Republic of Bahudhāñayaka was in evidence. The find provided archaeological confirmation of the description of the Yaudheyās of Bahudhāñayaka embodied in the Mahābhārata (Sabhāparvan, ch. 32, 4, 5), which put the seal of authenticity on the historical and geographical background of the great epic. It was hailed as a thrilling discovery by archaeologists and historians all over India. The late Professor K. P. Jayaswal announced Dr Sahni's significant discovery in his Presidential Address to the Numismatic Society of India, meeting at Udaipur in November 1936.

Because of his detailed study of the methods of coin

casting in ancient India, Professor Sahni was able to show that some supposed seals from Sunet near Ludhiana in Punjab, described in 1884 by Dr A. F. R. Hoernle, were in reality coin moulds in which some of the later Yaudheya coins must have been cast. Following up this clue, he came across a quantity of material which led him to conclude that Sunet probably marked the site of a later mint of the Yaudheyās, just as the Bahudhāñayaka mint at Rohtak had belonged to the earlier members of the famous warrior people.

After the death of Professor Birbal Sahni, the coin mould collection was presented by Mrs Savitri Sahni, his wife, to the Prime Minister, Pandit Jawaharlal Nehru. The collection is now housed in the National Museum, New Delhi.

VIII

The Floating Island of Khajiar

IN 1910, Professor Sahni, while still a student at Lahore, went on a trek from Pathankot-Khajiar-Chamba-Leh, and then back via the Zoji la Pass-Baltal-Amar Nath-Pahalgam and finally to Jummu. His first halt was at Khajiar, a small place in the erstwhile State of Chamba, now in Himachal Pradesh. At Khajiar, he stayed at a Dak Bungalow situated in a meadow besides a lake set in the midst of a dense forest, at a height of about 6,400 ft. above sea level. The meadow, oval in shape, gently slopes from the edge of the forest towards the marshland which surrounds the lake. A small island, thickly overgrown with tall reeds, *Phragmites communis*, glides over the water like a sail boat before a breeze. The depth of the lake is not known and tradition has it that the sacred waters of the lake are unfathomable and that the island moves by virtue of divine power. By the side of the lake, stands a little temple and a religious fair takes place there annually.

Professor Sahni noticed this peculiar floating island but did not leave the matter there. Being a true scientist, his interest and curiosity were aroused. He took keen interest in it and found that the island was densely covered with *Phragmites*, a genus which does not occur on the banks of the lake, nor within several miles of the locality. Several floating islands of the same kind were also reported by him in 1910, at Riwalsar, a small lake in the then Mandi State, now in Himachal Pradesh. Later Professor Sahni

was to learn that similar floating islets were present on the lakes in the southern Shan States of Burma.

He found that the conditions at Khajiar and Riwalsar were similar and concluded that very likely these two islands in two different places originated in the same way.

This island at Khajiar, a floating fen, he compared to those found in the Danube delta and elsewhere in the Broads of East Anglia, and in Kashmir. Under given climatic and edaphic conditions, the appearance of *Phragmites* marks a definite stage in the succession of plant associations thus· open water-submerged aquatics—floating leaf association—reed swamp association—reed-fen association. He concluded that "the existing floating fen of Khajiar owes its origin to a succession of phases in the vegetation similar to those observed elsewhere, that there once arose around the lake an extensive reed-fen, of which the present islet is the only persisting relic—and that the lake must at one time have been much larger". According to him, the concentric zones of vegetation were steadily moving centripetally and that the meadows were growing at the expense of the lake.

IX

Scientific Achievements

THE scientific achievements of Professor Birbal Sahni are far too numerous to be listed here. Only a few well known pieces of work can be mentioned. Among his outstanding works mentioned here are his researches on living plants like *Nephrolepsis, Niphobolus, Taxus, Psilotum, Tmesipteris* and *Acmopyle*, which have helped considerably in the understanding of their evolutionary tendencies, geographical distribution, their structures, affinities, etc. His contribution to the study of living plants is most creditable as he was basically a palaeobotanist. His first paper entitled, "On the presence of foreign pollen in the ovules of *Ginkgo biloba*, and its significance in the study of Fossil Plants," was published in the *New Phytologist* of 1915. His discerning power as a scientist at such an early age is borne out by the following observation that he made regarding this discovery. He wrote: "If a similar example was found in a fossil state, it would in all probability have led to a reference of the pollen grains and ovules to the same species," and again, "The mere fact of germination cannot be used in support of conclusions regarding the identity of fossil pollen grains found enclosed in ovules" This conclusion is remarkable as he had proceeded to Cambridge only a few years earlier in 1911. This observation showed his power of discerning and critical analysis, an insight which is so essential to the success of research.

His next paper (the *New Phytologist*, 1915) was regard-

ing the anatomy of *Nephrolepsis volubilis,* a peculiar fern with enormously long stolons arising from the mother plant. The stolons scale huge forest trees, produce lateral plants on them at intervals and often reach heights much above the mother plant. Professor Sahni studied the anatomy of the stolons of this fern and gave a detailed account of the manner in which the basal protostele of the lateral plants become modified into a dictyostele. From this, he proceeded to a study of the vascular anatomy of the tubers of *Nephrolepis cordifolia* (the *New Phytologist,* 1916). Soon after the publication of these papers, he submitted a dissertation for the Sudbury-Hardyman Prize, on the "Evolution of Branching in the Filicales," published in the *New Phytologist* of 1917. "Whereas, branches as a rule do not hold any regular position with respect to leaves, but those cases where this association is present," he wrote, "the association is in its evolutionary origin a secondary phenomenon attributable to possible biological advantages, one of which may be the protection of the young bud."

In 1919, Birbal Sahni submitted his thesis for the degree of Doctor of Science (D. Sc.) of the London University, and the research findings were published next year in the Philosophical Transactions of the Royal Society. For his thesis he made an exhaustive study of the anatomy and morphology of the rare and little known conifer *Acmopyle Pancheri,* found in New Caledonia. The specimens had been collected in 1914 by Professor R.H Compton of South Africa and were fragmentary and poorly preserved and it goes to the credit of the young researcher that in spite of such a big handicap, he still managed to study them and to write his doctoral thesis on it.

Dr Sahni discussed the relations of the cordaitales to the pteridosperms and the conifers. Though he did not

completely reject the prevailing idea that the cordaitales were derived from the pteridosperm stock, he advanced strong arguments against this view. On the basis of one important morphological feature, he suggested a division of gymnosperms into two new groups. One, *Phyllosperms*, which had seeds borne on the leaves, and two, *Stachyosperms*, in which the seed is seated directly on a normal or a modified axis. This distinction into 'Phyllospermy' and 'Stachyospermy' has now been extended to apply to the position of all sporangia in vascular plants. It is interesting to note that what Professor Sahni said regarding placing the three genera *Taxus*, *Torreya* and *Cephalotaxus* in a separate order Taxales, because of their definite peculiarities and differences from the rest of the conifers, as early as 1920, has now been accepted by Florin (the *Botanical Gazette*, 1948).

On returning to India in 1919, Dr Sahni took stock of the palaeobotanical work done in India and the possibilities that such a study offered. In 1922, in his Presidential Address to the Botany Section of the Indian Science Congress Association on "The present position of Indian Palaeobotany," he said, ' My own interest in Palaeobotany raises the hope that I may help to bring this fascinating subject more prominently to the notice of my countrymen, and perhaps even succeed in inducing a large number of them to turn their attention to the rich field that it offers for original investigation. With this end in view, I propose to devote my address to a brief review of the present position of Indian palaeobotany."

The most important point which Professor Sahni recognised was that all palaeobotanical studies must be made in relation to the geological and geographical conditions under which the plants under investigation lived and died. Also, that without a proper understanding and appreciа-

tion of this geological background, the study of fossil plants loses practically all their vital interests.

In 1924, Professor Sahni was elected President of the Indian Botanical Society which three years earlier had been founded mainly by his own efforts and with the close collaboration and efforts of botanists like Professor W. Dudgeon of Allahabad, Dr S.R. Kashyap of Lahore and Dr K. Rangachari of Madras. The subject of his Presidential Address was, "The Ontogeny of Vascular Plants and the Theory of Recapitulation."

In the year 1866, Haeckel propounded the famous doctrine that during their individual development, organisms tend to recapitulate their racial history. Professor Sahni said in his address: "The structure of an organism at all stages of its life is a reflexion of its past and present experiences, a combination of characters acquired both in the wide sense, that is, from previous generations and in the narrower sense, from its immediate environment. And it is significant that when the normal equilibrium is upset by adverse conditions, adjustment is often effected by a 'fallback' upon the surer basis of past experience. Herein lies the rationale of the interpretation of so-called 'abnormalities' (as apart from obvious monstrosities) as being in the nature of reminiscences of the past, when they formed part of the normal and stable organisation in some more or less remote ancestor."

This theory had so far derived all its support from the zoological side and had emerged from a mass of observed facts in the field of animal embryology and palaeontology at a time when the theory of evolution was still fighting its battle for recognition. One would have expected that a biological principle of such a fundamental nature would apply equally to the animal and plant kingdoms. Professor Sahni showed that there was an equal case in

support of the theory on the botanical side also which was a big landmark in the application of the theory to evolutionary trends in Botany. In this paper he pointed out several examples amongst vascular cryptogams, gymnosperm seeds and angiosperm flowers which showed that the well-known biological principle, 'Ontogeny tends to repeat phylogeny', occurs in plants as well.

In 1929, Professor Sahni was awarded the degree of Doctor of Science (Sc. D) by the University of Cambridge. He chose material for his research work for the doctoral dissertation mostly from those groups of plants which invite comparison with the fossils. He adopted a phyletic approach in his morphological interpretations, and this has been named, "The New Morphology" (H. Hamshaw Thomas, 1931).

Professor T.G. Halle of Riksmuseum, Stockholm, commenting on Professor Sahni's work says·

> "His discussion of phylogenetic relationships at this time throws a vivid light on his analytical mind and his interest in general problems. But they also show that at an early date he had acquired a remarkably extensive knowledge of the morphology and anatomy of both living and fossil pteriodophytes and gymnosperms. One cannot but be impressed with the large amount of high class work which he crammed into the years he spent at Cambridge, dividing his time, as he did, between various little related and most difficult subjects."

While still at the Botany School, Cambridge, Birbal Sahni published his first contribution to pure palaeobotany, though on two widely different groups of palaeobotanical subjects, viz. (*i*) The anatomy and morphology of Palaeozoic ferns; (*ii*) The fossil plants of the Indian Gondwana

formation. His interest in the study of fossil botany was inspired by his teacher, Professor (later Sir) A.C. Seward, an interest that lasted all his life. Professor Sahni often acknowledged this and frequently expressed his gratitude to Professor Seward who was the Founder of the Cambridge School of Palaeobotanical Research in the same way as Professor Sahni was the pioneer of palaeobotanical research in India.

I. ANATOMY AND MORPHOLOGY OF PALAEOZOIC FERNS

Professor Sahni concentrated his research work on the Palaeozoic fern-like plants, the Coenopteridineae, especially on the family Zygopteridaceae, an entirely extinct group. Whereas this group is of extraordinary interest, it also presents unusual difficulties as a subject of research because this material is fragmentary in spite of its being well preserved. The fragments of the fossilised plants are found as pieces of petrified stem, but more often only pieces of leaf stalks and rachises of leaves are found preserved. The leaf lamina and the sporangia are seldom preserved. And a connection between the various parts of the plant material available has of necessity to be made by comparative studies. But with such fragmentary material it is very difficult to judge the habit of the plant. Comparative studies was a line of work in which Dr Sahni was to play a leading role. Even at the start of his career as a palaeobotanist, he had done considerable research under Professor Seward on the anatomy of living ferns which was an essential pre-requisite for the study of fossil anatomy.

Sahni's deep interest and continued investigations of the Zygopteridean stem resulted in many publications spread over a large number of years (1919a, 1928d, 1930a, 1932c).

The structural features of this stem have peculiar combinations of characters and this resulted in different generic names being given to various specimens of the plant at different times. These names are: *Zygopteris*, *Ankyropteris*, *Clepsydropsis* and *Austroclepsis*. Quoting Professor Halle: "By examining a large material and fitting together various fragments, Sahni was able to give an unexpectedly complex account of the anatomy of the stem and also to picture the extraordinary habit. He found that the plant was a large tree-fern with an almost unique type of trunk; numerous slender, bi-furcating axes are embedded in a thick mass of adventitious roots and aphlebiae and thus kept together so as to form a 'false stem', somewhat reminiscent of that of the Cretaceous genus *Tempskya*."

Subsequently, Professor Sahni named the new genus from Australia as *Austroclepsis*. Dr Sahni's later work on *Austroclepsis* was much influenced by his investigations of another species, which he also referred to a new genus *Asterochlaenopsis* (1930a). This species has a curious history. A fine petrified stem of a tree fern from Siberia had long before been cut transversely into several slabs, some of which must have found their way to different museums in Germany. When Dr Sahni began to search for the pieces, they were no longer known to belong together: two of them had even been described as species of two different genera: *Asterochlaena* and *Rhacopteris*. By re-discovering and fitting together these two fragments, Dr Sahni could prove that they were actually parts of the same specimen. His reconstructions of the stem, incorporating three other pieces as well, revealed another interesting combination of characters. The petioles were of the *Clepsydropsis* type, but the leaf-trace sequence resembled that of *Asterochlaena*, and the previous unknown stele proved to be a type somewhat intermediate between those

of *Asterochlaena* and *Ankyropteris.*

Professor Sahni's first paper on these plants was an intense and critical study of the branching system of the Zygopteridean leaf (1918). This family is remarkable for the unusual branching of the compound leaf. Whereas in most genera, the primary pinnae are found placed in four rows, two on either side, so orientated that they are at right angles to the mother axis but in this particular type of leaf, they combine the characters of both stem and leaf.

It might sound a trivial matter to the uninitiated student of botany, but actually Dr Sahni did a lot to clear the confusion surrounding the nature and affinities of *Clepsydropsis* which work was highly significant as the genus has played an important role in the discussion of the Coenopteridineae as it has been regarded as a type of the family and its interpretation has affected the very basis of classification in a considerable part of the whole group.

Sahni, during his tour of Europe in 1929, collected material for investigations of an obscure species called *Zygopteris primara* (Cotta) Corda. The genus *Zygopteris* included many species, all except one of which were later transferred to other genera. The species *Zygopteris primara* had been founded on the structure of fern petioles preserved in a silicified specimen from the Permian of Chemnitz in Germany The general belief prevalent then was that this was the only specimen of the genus, but actually, sawn off parts of the same specimen had been scattered in various museums of the world. Dr Sahni travelled to various countries and studied the fragments of the petrified petioles of the specimens in half a dozen museums in England, France and Germany, and identified them as belonging to the same piece. In Berlin, he saw another specimen where a protostelic stem had been preserved. Dr Sahni here again reconstructed the plant and found that it was a tree-fern

with a slender axis supported by a large number of petiole bases and adventitious roots From the investigations of its anatomy, the stem, the leaf-trace sequence and its roots, it was found to be of the type previously described as *Botrychioxylon*, while the petiole anatomy showed the characteristic structure of the stem described as *Etapteris*. This gave the salient features of three genera all combined in one single specimen. Similarly, in his work on *Grammatopteris Baldaufi* (1932g), Sahni studied and compared the scattered pieces of a petrified stem from the Lower Permian of Chemnitz, discovered in 1915. By interpreting the structure of the stem and analysing its affinities, he showed convincing evidence for removing *Grammopteris* from the Botryopteridaceae, and placing it in the Zygopteridaceae.

Professor Sahni always followed definite lines of study for which he had often to hunt for specimens in various museums of different countries and to trace their history. A very characteristic feature of such a hunt for old specimens and their study resulted in placing the different specimens into the same genera and species, almost like fitting pieces into a zigsaw puzzle.

2. GONDWANALAND

The Indian Peninsula, where the majority of the known fossil plants were discovered, is one of the most ancient land-surfaces of the globe During the Mesozoic era, it was a part of a vast continent stretching from South America, through Africa to Australia. This means that it covered the vast areas at present occupied by the South Atlantic and Indian Oceans. This hypothetical southern continent was called Gondwanaland by geologists. It was bounded on the north by an extensive ocean separat-

ing it from a vast northern land-mass which joined up the present continent of North America and Eurasia. Great earth movements of a violent character shook this land-mass during the Tertiary era, resulting in a break-up of the Gondwana Continent. A greater part of it was engulfed by the ocean and isolated peninsulas were left which are the present peninsulas of South America, Africa, India and Malaya, and the Australasian Archipelago with its island continent of Australia.

Towards the end of the Carboniferous age, an extensive glaciation on the Southern hemisphere killed out most of the older vegetation. The area affected must have been very great as can be "imagined by the fact that at a level in the stratigraphical scale corresponding to the Upper Carboniferous of Europe, there occurs in Australia, India, Malaya, South Africa and even in South America, a glacial deposit of a remarkably uniform character in all these distant countries. All available evidence from fossils points to a relatively cold temperate climate and it is surmised that in the later stages, the climate must have warmed up sufficiently to maintain a rich vegetation which yielded thick seams of coal. There is ample geological evidence that at this period of the earth's history, a great mediterranean ocean, the Tethys, separated the northern and southern continents. India formed an integral part of this southern continent with its northern coast roughly following the trendline of the present Himalayan Range. The geological data and the palaeobotanical facts available point to the belief that India was under ice during the Upper Carboniferous period and in any case not later than the Lower Permian. Even Professor A.C. Seward, in spite of his very cautious attitude regarding the evidence in climatological value of fossil plants, agreed that "the climate of Gondwanaland was doubtless comparatively

cold well into the Permian period and much less genial than that of the northern continents."

Professor Sahni's interest in the Indian fossil plants, especially from the Gondwanas, was aroused as early as his Cambridge student days. Specimens of the fossil plants sent to Cambridge by the Geological Survey of India were studied by him and by Professor Seward and their investigations appeared in a joint publication: 'Indian Gondwana Plants, a Revision, 1920b'. The Revision was based partly on new information available on morphological and anatomical matters and partly on the study done on cuticular structures of the Lower and Upper Gondwanas. By a study of the Palaeozoic flora of the Lower Gondwanas, a resemblance was established between the northern and the southern floras. And by the discovery of a species identified as a conifer resembling *Torreya* and given the generic name *Torreyites*, the important northern group Taxales was shown to have extended to Gondwanaland in Jurassic times.

For his next important publication, 'Revision of Indian Fossil Plants', he had coniferales as the subject. This appeared in two parts, one dealing with Incrustations and Impressions (1928c), and the other with Petrifactions (1931c). Most of the fossils came from the Gondwana formations and a few were derived from the Deccan Intertrappean beds. These are now generally placed in the Eocene epoch. The revision and review of the fossil plants included descriptions, illustrations, discussions of the material found scattered and placed in the correct order, as well as a summary of their stratigraphical and geographical distribution. A very interesting result of Professor Sahni's 'Revision of the Fossil Flora' was the difference found between the conifers from Europe and those from India, and also the differences in the fossil floras of south

and north India. For instance, the material found from peninsular India did not have a single example of the typical north Indian families, Pinaceae and Cupressaceae, nor of any genera of the Taxodiaceae.

Professor Sahni made a comparative study of the fossil floras of the various components of the Gondwana Continent and listed the various fossil plants discovered. This exercise was undertaken to find out how palaeobotanical evidence corroborated the Wegner hypothesis of Continental Drift.

3. THE THEORY OF CONTINENTAL DRIFT

WEGNER was one of the scientists who conceived the idea that the different continents of the earth have broken apart from a joint land-mass which was called Pangea. A striking evidence for this is the resemblance in the outline of the eastern coast of South America and the western coast of Africa. There are certain plants and animals in these two countries, separated by a vast ocean, which are very similar and it seems that this similarity is due to their having grown together at one time in a common land-mass which later broke up into different pieces. Distribution of fossil plants of the Late Palaeozoic Era very strongly supports the theory of these continents having been united at one time.

In 1935, Professor Sahni wrote that he agreed with the theory that the drift movements of a large magnitude elsewhere had brought into juxtaposition continents once separated by wide oceans. In India the *Glossopteris* flora probably ranged from the Upper Carboniferous to the Trias. The lower limit is indicated by the relations of the Talchir glacial beds and the earliest plant-bearing Gondwanas with marine fossiliferous horizons of determinable

age, particularly in Kashmir and in the Salt Range.

Among one of the valuable contributions made by Professor Sahni to palaeobotany was his description of *Glossopteris*. Leaves of this type of plants were known for almost a century and had been regarded as fern leaves. But his work showed that the plants had leaves, the characters of which are now known to exist only in the leaves of seed-bearing plants. He was greatly interested in the problems connected with the relations of the *Glossopteris* flora to the contemporaneous northern floras and to the Gondwana Ice Age. He did a lot of study, correlating the fossil flora of India with those of the rocks of the southern hemisphere and to the geographical and geological implications of these correlations. Evidences suggested that the characteristic plant *Glossopteris* grew under cold temperate conditions, and its abundance in India as well as in South Africa, Australia, South America and Antarctica was therefore remarkable. The problem became complicated with Professor Halle's discovery of a large flora, *Gigantopteris*, in China, as this discovery suggested that the plant had grown under moist tropical conditions and that the said flora had extended southwards into central Sumatra.

A little later, Professor Zalessky discovered that the Angaraland flora had spread southwards to within a few hundred miles from Kashmir, which was the northern limit of *Glossopteris*. Sahni considered that all these facts could only be explained on the hypothesis of Continental Drift. He thought that the peninsula of India had once been a part of an old continental block, the Pangea, which had drifted into close proximity with the land-mass forming the main Asiatic Continent.

According to Professor Sahni, if the *Glossopteris* flora of India and Australia flourished in a climate distinct from that of the Sino-Sumatran province, then there is no

escape from the conclusion that the two provinces originally lay far apart, north and south of the Tethys sea and have since drifted towards each other. He concluded that the drift movements of large magnitudes elsewhere had brought into juxtaposition continents once separated by wide oceans. He also said that there was a sharp angle in the strike of mountain ranges in north-eastern Assam, and in the southern extension of the Himalayan axis as far as the Malaya Archipelago. "If the Himalayas are still rising, as some geologists believe, then we may conclude that the northern and southern continental blocks are still pressing towards each other; and if the sharp knee-like bends in the axis of the Himalayas have been formed, as suggested, by rotation round the two pivots of Kashmir and Assam, then accurate longitude records carried over a number of years may show that the distance between points in Baluchistan and the Shan plateau is still becoming shorter." He concluded that "although on the whole the *Glossopteris* flora of India and Australia on the one hand and the *Gigantopteris* flora of China and Sumatra were very distinct, it appeared that during Permo-Triassic times, some intercourse across the Tethys seems to have been possible between India and the Far East, as also between the Gondwana and Angora Continents. This is indicated by stray Gondwana elements both in the Far Eastern and in the Angora Flora."

Regarding the prevalence of European element in the lower Gondwana floras, he believed that some species had survived the glaciation in refuge areas in Gondwanaland. About the time that Professor Sahni was studying the plants of the Lower Gondwanas, lot of research work was being done on the contemporaneous floras of Siberia, China, Korea and Sumatra. Sahni was greatly attracted by two analogous problems viz., the relations of the Lower

Gondwana flora and, its relation to those of China and Sumatra.

Quoting from Professor Sahni's paper on the Theory of Continental Drift, the position becomes very clear: "This floristic contrast is so striking as by itself to raise the suspicion that the two floras, one essentially northern, the other southern, must have lived in different climates. Indeed, the current view is that the *Glossopteris* flora was probably evolved in a temperate climate on a continent just emerged from glaciation, the *Gigantopteris* flora in a warmer climate analogous to that of the European coal measures."

4. THE DECCAN INTERTRAPPEAN SERIES

Professor Sahni's work on the Mesozoic plants was mainly concerned with the Jurassic material, particularly of the Lower Cretaceous flora of India. In this connection, his most significant contribution was the investigation of the silicified flora of the Deccan Intertrappean Series.

The Intertrappean beds are layers of sedimentary rocks occurring in between the silicified masses of land which are known as Trap rocks. These Trap rocks having originated from molten lava are devoid of any organic remains. In between layers of Trap rocks are strata where organic growth must have occurred leaving its past life behind, as it is in these Intertrappean deposits that fossil plants and some animals are found. The Deccan Intertrappean plant fossils are some of the best examples of petrified remains in India. The siliceous fresh water sediments (cherts) interstratified with the Deccan Traps contain an abundance of plant remains of various kinds, often well preserved enough to merit examination of its most delicate structure. This phenomenon, Professor Sahni explained by saying

that if volcanic ash settles on a lake or a river that happens to be nearby, it forms a sort of volcanic sediment in which the creatures living there find a speedy but immortal grave. The bodies of these plants and animals are preserved imperishably, particle for particle, cell for cell, the plant tissues replaced by silica derived from the ash, or from a lava flow that might have overflowed the lake and finally an exact replica of the original is left in hard indestructible silica, called a petrifaction. The fine state of preservation of the plants in both the areas is probably due to their having been suddenly overwhelmed by showers of volcanic ash or fluid lava, thereby sealing up the organic remains and preventing their transport to any distance before they became petrified.

The most beautifully preserved plant remains, found in the cherts round Sausar in the district of Chchindwara, are the common species *Azolla intertrappean,* a water plant. The cherts represent silicified lake muds, sometimes mixed with volcanic ash deposited on stagnant water. This Deccan species of *Azolla*, belonging to the Tertiary period, having lived 60-70 million years ago, affords an impressive example of the persistence through the ages of a highly specialised type of behaviour during the reproductive phase of the life history of a genus.

Professor Sahni studied the fossil plants and extended his anatomical studies to this material also. In 1925, the Director of the Geological Survey of India sent to Professor Sahni blocks of plant-bearing cherts and in one of them, Professor Sahni found petrified remains of angiosperms (modern flowering plants), which are exceedingly rare in older fossil floras and he immediately recognised their great importance as they invite comparisons with the rich carbonised material of similar fossils from the Lower Tertiary of Europe, which has been found to contain a

large percentage of modern Indo-Malayan elements. The monocotyledons (seeds containing only one leaf, called a cotyledon) of the Intertrappean beds have some very interesting material and the petrified palm stems found there were included by Sahni for a comprehensive study. Sahni's work on the Intertrappean gymnosperms (a group of plants commonly known as Pines, Firs, Spruce, Junipers etc) was chiefly from the silicified cones of conifers and the most important of them belong to the two genera *Indostrobus* and *Takliostrobus*. These two new genera found by Sahni are particularly interesting as they show a combination of characters from the Abietinean and Podocarpaceae, but he left the question of their phylogenetic relationships open.

Professor Sahni's interest in the Intertrappean flora was not only confined to the structure and affinities of the plants but was often on subjects of their ecology, geographical relations and the geological age of these floras. This aspect of his research was interesting from the point of view of knowing the type of flora that existed at that period and was important from the geological angle also. All the same, Professor Sahni was cautious not to draw conclusions regarding ecological conditions in the geological past from a study of individual fossil forms as compared with modern types. But he could deduce from several palaeobotanical facts previously found that the northern part of the Deccan, round Nagpur and Chchindwara, was not far from a sea-coast during the Intertrappean period, and that a close relative of the modern estuarine palm *Nipa fructicans* existed in the region now known as Mohgoan Kalan, as a fossil fruit of that genus was discovered there. From the same geographical region, another fossil closely allied to the modern coconut palm was also discovered. On several occasions, Professor Sahni pointed out the close

analogy between the flora of the Deccan Intertrappean beds and that of the Eocene London Clay, as the fossilised fruits of *Nipa* are by far the commonest fossils in the London Clay. These brackish water plant fossil records give the rough coastline of the old Tethys sea which must have swept the northern shores of the Deccan not far from where Chchindwara now stands. His researches clearly showed that in the Deccan Trap period, Peninsular India had a vegetation of the same general character as that of western Europe in the Early Tertiary times.

Professor Sahni described the Primeval landscape of India, reconstructed from the available geological, palaeontological and climatological evidence, in his Presidential Address given at the Twenty-seventh Indian Science Congress Session, held at Madras in 1940

> ". . . I would ask you to bear with me if I seem at times to be telling a fairy tale. For at this distance of time we can only see a dim outline of the world as it was, and the exact language of science is ill-suited to the description of visions.
>
> Competent authorities place the dawn of the Tertiary era between sixty and seventy million years ago. It is the birth of a new era in a very real sense. Stupendous forces, surging in the womb of the earth, had already caused gigantic rifts in the crust, and these rifts are gaping out in the oceans. From smaller fissures in the crust, molten rock is now pouring forth in repeated floods of lava which will cover millions of square miles of land and sea. Vast areas are being converted into a desert by showers of volcanic ash. A new type of landscape develops, with high volcanic plateaus as a dominant feature. The face of the earth is rapidly changing. She puts on a more modern garb of vegetation, the

land, lakes and rivers become peopled by creatures more familiar to us. Still there is no sign of man. But the stage is being set for his arrival. For this critical period foreshadows the birth, out of the sea, of the mightiest mountains of the world; and the heaving bosom of the earth, somewhere to the north of India, is to be the cradle of man.

Such was the Eocene age: it was literally a 'cradle of the new.'

By far the greater part of the Indian peninsula is made up of rocks that have solidified from a molten state. But the igneous activity which these rocks indicate took place in distinct periods separated from each other by a span of time of which no adequate estimate is yet possible.

The eastern and southern portions of the peninsula form one of the most ancient land surfaces of the globe. Parts of it are believed to belong to the primeval crust of our planet as it first cooled and condensed from a gaseous or liquid mass.

From time to time other molten rocks from the interior have burst through this crust and solidified in the cracks, forming thick sheets or walls cutting across the older rocks. The early convulsions of the earth, while she was young, are still recorded in the complex folds into which these archaic rocks have been thrown. Over large areas the original rocks have been fractured by earth movements and so badly crushed and altered that we can no longer tell their mode of origin.

This was the kind of primitive landscape on which long afterwards, life first originated (in water) and on which the stratified crust of the earth was laid. With the passage of time the greater part of this crust has worn away, and the old surface has again been laid

bare. But portions of the strata still remain, protected in deep trough-like hollows in the old river basins, the Mahanadi, the Godavari and the Narmada, and in a string of outlying patches along the east coast, from Trichinopoly to as far as Cuttack. These deposits were laid down chiefly in lakes and rivers, but partly also in shallow seas that flooded the land from the north and east The wealth of evidence these strata contain tells of great changes of climate and of a long succession of floras and faunas that lived on the vast southern continent of which India once formed an integral part.

Except for these temporary incursions of the sea, the plateau of the Deccan has remained a land area, so far as we know, ever since the original crust was formed. . ."

Talking of the Deccan before the eruptive period, he says, "the northern sea has also overflowed the land, in the region of the lower Narmada. But the fauna here is very different, because the barrier of the plateau cuts it off from the southern sea. The northern fauna is more allied to the European . . . in fact, the same ocean stretches on one side into Europe and on the other as far as Tibet and China.

"But of our western coast at this period there is no evidence; either India has not yet split away from Africa; or what seems more likely, it has brought away with it a large tract of land which lies to the west. By the sinking of this tract the gulf between India and Africa will widen out into the Arabian Sea, isolating our triangular island of the Deccan which, like a gigantic raft that has been cut adrift, will continue on its long journey to the north-east.

"Amongst the denizens of the land, dinosaurs abound in the forests of the Central Provinces. Many of them belong to types peculiar to India but, strangely enough, they have

their nearest relatives among the dinosaurs of Madagascar and South America; there must still be some land connection left that allowed these reptiles to intermigrate. But they are rapidly running out their race. The last of the Indian dinosaurs lie buried in the Lameta beds near Jabalpur and at the village of Pisdura near Warora, to the south-east of Wardha."

5. THE KAREWA SERIES OF KASHMIR

THE Kashmiri name Karewa is applied to the more or less flat terraces or tablelands which cover a great part of the valley, especially on the left bank of the river Jhelum.

As far back as 1936, Professor Sahni had pointed out plenty of palaeobotanical evidence in the Karewa deposits of Kashmir which supported the theory of the Pleistocene upheaval of the Himalayas as suggested by him. The presence of fossil remains of sea animals on the crest of the Himalayas and lake deposits containing relics of aquatic plants and animals found on the elevated slopes of mountains of Kashmir often led to the erroneous belief in the mind of the lay person, that the mountain tops must have at one time been submerged in an ocean and that lakes must have existed at high levels. Fossil remains of aquatic plants and animals, including modern species of these plants and animals in lake deposits, have been found to occur on the slopes of the Pir Panjal Range, at altitudes where these species cannot exist today. The significance of these high-level deposits known to the geologists as the Karewa Series was explained by Professor Sahni, thus: "The fossil-bearing sediments near Gulmarg (8,800 ft.) like other deposits of clay, sand and gravel, on the North-East slopes of the Pir Panjal, were no doubt laid down, as Dr Stewart suggests, in the bed of a lake. *But that lake never*

existed at the high altitudes where its bed is now seen. Strange though it may seem, this lake must have been situated several thousand feet lower, at the same level as the main valley of Kashmir. Since the time when the plants and the animals of which the fossil remains are now found at 11,000 ft. or even higher, flourished in and around this lake, the sediments have been lifted out of their original horizontal position and have been upheaved through at least five thousand feet with the (geologically speaking) recent upheaval of the Pir Panjal Range."

The Karewa formation of Kashmir, from an elevation of 10, 600 ft , revealed a flora characteristic of sub-tropical rain forest conditions consistent with the flora of an altitude of 4,000-6,000 ft. In India it is difficult to explain a warm flora having existed at an unusually high elevation. According to Professor Frederick E. Zeuner, "This could only be explained in two ways. Either the climate was such in Karewa times that the flora in question could grow some 5,000 ft. higher up than at the present, or the beds containing the flora were lifted up by earth movements after they had been formed. That climatic changes occurred in the course of the formation of the Karewa beds is likely, since varved deposits are included in this series. They suggest glacial phases." "It is easy to interpret a cold climate flora found at an unusually low elevation by assuming a glacial phase," according to Sahni. Sahni and others have shown that this upheaval could only be connected with the formation of the Pir Panjal Range. The recent elevation of the Pir Panjal Range is only a small part of the vast upheaval which has affected the main Himalayan Range on one side and the Potwar plateau (between Rawalpindi and Jhelum, now both in Pakistan) on the other, during the period when man already existed in this part of the world.

According to Professor Sahni,". . . in places the Karewa beds rest upon an ancient rock-bottom which shows unmistakable signs of having once been scratched and polished by glaciers, dragging over the old surface their tremendous weight of ice, and its contained rock-debris of 'moraine'. Elsewhere we find fossiliferous clays, containing evidences of life in a temperate climate such as the shells or skeletons of modern fresh water animals or the leaves of familiar forest trees, *inter-bedded with deposits of undoubted glacial origin, indicating arctic conditions*." ". . Under the meadowed moraines of Gulmarg itself, which provide such excellent golf links, fossiliferous interglacial clays are exposed at several places on the banks of the meandering brooks Some of them are almost black with decayed plant-remains, others, of a blue grey colour, are crowded with the shells of fresh water mollusca, chiefly gasterpods. They remind one of times when this area lay at a considerably lower level and was covered by a lake teeming with animal life. Then came a cold wave, and glaciers from Toshmaidan and from the heights we now know as the Apharwat descended upon the lake, loaded with debris torn from the rocks in their downward path. With the final melting away of the ice the confused mass of sand, clay and angular boulders of various sizes was left behind in mounds, more or less as we find them today."

All this fits in with the well-known tradition of Kashmir, a tradition that goes back to time immemorial that the valley of Kashmir was formerly occupied by a lake. The physical features of Kashmir fit in very well with the tradition of the country. The various lakes of Kashmir, the Dal, the Manasbal, the Wular and hundreds of other smaller lakes dotted over the landscape of the valley, are but the shrinking remnants of this great pleistocene lake on whose shores lived Palaeolithic Man.

6. THE PO SERIES OF SPITI

PROFESSOR Sahni, in a joint publication with W. Gothan in 1937, described a few important Lower Carboniferous plants from the Po Series in Spiti. The name Po Series was given after the village Po in Spiti, in the vicinity of which the fossils were found. These comprise some two thousand feet of shale and quartzites forming the upper part of the Kanawar system. The Series is divisible into two parts. The lower part consists mainly of dark-coloured shales which have been much altered by igneous intrusions but locally the shales are unaltered and have yielded fragmentary leaf impressions. The upper part of the Series is called the Fenestella shales and contains a rich marine fauna.

These fossils have been earlier identified by Zeiller and the above-mentioned two authors confirmed his conclusions which implied that the fossils are remains of the pre-glacial flora. This flora was recorded from other parts of Gondwanaland and appeared to have been more or less uniformly spread over the globe. In the controversy over the geological age of Gondwana glaciation, he maintained that the Ice Age must have set in long before the close of the Carboniferous period.

Ice had swept through the northern hemisphere to the southern hemisphere, and forced many forms of life to disappear from the surface of the earth. Swamps were drained off and dried, great mountain ranges appeared everywhere; plant and animal life, terrestrial or submerged, was forced into new ways of existence if it was to continue. The giant mosses and tree-ferns disappeared and the land under the changed climatic conditions responded in a variety of ways. In between the Ice Age were inter-glacial periods of relative prosperity where plants and animals

flourished and some species had adapted themselves to relatively cold climates within limits. On various occasions, Sahni expressed his agreement with the view that the Ice Age broke the dominion of the cosmopolitan flora *Glossopteris*.

7. THE RAJMAHAL SERIES

THE Gondwana plants from the Jurassic Rajmahal flora were the dominant passion of research for Professor Sahni. Geologists like Oldham, Morris and Feistmantel had earlier worked on the Upper Gondwana beds of the Rajmahal Hills, but when Sahni started his research, a new epoch opened and he discovered a large number of peculiar and interesting fossil plants. He found some new species and two new genera, namely, *Ontheodendron* and *Rajmahalia*. Whereas Rajmahal material contained both impressions and petrified specimens, it was the petrifactions which formed the main subject of his research on fossil plants from that area.

Among the important contributions of Professor Sahni's research work was his study of the fossil *Williamsonia Sewardiana* (1932f), which added much to the already existing knowledge of the order Bennettitales. Though this group was already known to exist in the Rajmahal Series as stems, leaves and the so-called 'flowers' (the plant does not bear flowers as seen on the present day plants), but except for a solitary specimen, all the others were detached pieces and, therefore, difficult to reconstruct as belonging to one plant. Professor Sahni's investigations were concentrated mainly on two specimens from Amrapara in the Santhal Paragana district of Bihar. One of the two specimens bore leaf-scars, remains of rachises, bract and a female flower. This flower was identical to the description

given of a flower of *Williamsonia scotica* and by careful comparison, Professor Sahni could prove that the flower belonged to the same kind of plant as the *Bucklandia Indica* stems, and to the *Ptilophyllum* leaves. He gave the new name of *Williamsonia Sewardiana* to the whole plant.

A silicified shale, rich in fairly well preserved petrified plant remains, is found in Nipania and Amrapara in the Rajmahal Series. Professor Sahni organised special collecting tours and, in the company of his students and assistants, collected a very large number of specimens. In fact, the last tour he conducted, three months before his death, was also to this area.

8. THE PENTOXYLEAE

THE greater part of the material found by Professor Sahni in the fossiliferous areas of the Rajmahal Hills of Bihar was silicified and well-preserved, but some Impressions were also discovered. The petrifactions have been found to occur in considerable abundance at the village of Nipania in the Rajmahal Hills near Dumarchir in the Amrapara district, Santhal Paraganas of Bihar. They were all found in a single thick bed of secondary shale, a rich fossiliferous lake deposit. These fresh water shales were interbedded with an extensive series of lava flows associated with volcanic ash and like the Deccan plateau, these volcanic rocks often formed terraced hills giving a striking and beautiful appearance to the landscape.

The Rajmahal Hills yielded specimens of great significance and Professor Sahni described some of the important genera from there. These genera included *Homoxylon rajmahalense*, *Rajmahalia paradoxa* and the well-known specimen *Williamsonia Sewardiana*. However, his most significant contribution to fossil botany was the discovery

of a gymnosperm of extraordinary importance to the subject of palaeobotany, and he proposed the name *Pentoxyleae* for the new discovery. The progress of his investigations on the fossils from Nipania and Amrapara makes an interesting connected story. The form genus *Taeniopteris* was known to include plants belonging to the ferns, the Cycadales and the Bennettitales. Professor Sahni found that the structure of the mesarch vascular bundle in the midrib of the Nipania leaves agrees almost exactly with that found in the modern Cycads. The group Pentoxyleae combines features suggestive of the coniferales, the Bennettitales and the Cycadales But in the morphology of the inflorescence and of the cones and especially in the vascular anatomy of the stem, it stands isolated. The Pentoxyleae investigations luckily reached their decisive stage in time to be included in Professor Sahni's last palaeobotanical publication. Because of the importance of this last piece of research done by Professor Sahni, it was considered but right that a design based on his reconstruction of Pentoxylon should be chosen for the seal of the Birbal Sahni Institute of Palaeobotany.

9. THE SALINE SERIES

In 1944, Professor Sahni announced his discovery of microfossils in the Saline Series of the Punjab Salt Range which clearly indicated that the Saline Series could not be of Cambrian Age, but was post-Jurassic, very likely Eocene. Microfossils are fossilised remains like spores, cuticles, pollen grains, epidermal layers, etc.

For over sixty years, the age of the Saline Series had been baffling the geologists. In 1902, two German geologists, Professor E. Koken and Dr F. Noetling, suggested the rather sensational idea that, ". . . although the Saline

Series actually lies beneath the Palaeozoic sequence, it is geologically far younger than the latter, and is of early Tertiary (Eocene) age". According to them, it owes its lower position to an 'overthrust' movement of vast magnitude which has shoved the entire column of Cambrian and younger beds (totalling some thousands of feet in vertical thickness) bodily southwards for a distance of many miles so as to bring it to rest on top of the Saline Series.

Professor Sahni's interest in the Salt Range of Khewra goes back to almost his childhood days when he, in the company of his father and brothers, used to trek in that area during the summer holidays. Professor Sahni was attracted to this problem for a very long time and stated in 1947 . . . "About four years ago, while with a party of students in the Salt Mines of Khewra, it occurred to the author to dissolve a little of the Saline earth and to examine some drops of the brine under the microscope. The idea was that since the salt must have been formed from sea-water by the drying up of a bay or a lagoon, the brine ought to show at least some minute traces of organic remains which might give a clue to its geological age. The surmise proved to be correct: quite a large number of little shreds of woody tissue of dicotyledons and conifers as well as the chitinous remains of winged insects were discovered. These fragments had no doubt been washed into the water or wafted on to its surface by the wind; and it was clear that if these creatures were alive at the time the sea existed, the salt could not possibly be so old as the Cambrian."

The results of these sample tests conducted by Professor Sahni made him conclude that Professor Koken and Professor Noetling were right in their suggestion and wrote· "The Saline Series must be much younger than the strata lying above it, and this can only be explained on the view that the entire Series of Palaeozoic and overlying

beds up to the Tertiary have been bodily thrust from North to the South for a distance of many miles, presumably gliding or 'skating' over a sort of lubricated floor formed by the soft and highly plastic rock-salt and gypsum at the top of the Saline Series."

Professor Halle also confirmed these theories and commented: "This meant that the whole packet of Palaeozoic-Mesozoic beds making up the bulk of the Salt Range must have been pushed over the underlying Salt Formations by an immense overthrust."

But Professor Gee and some other geologists did not agree with Professor Sahni's hypothesis and maintained that the Salt Series of the Salt Range is in its normal stratigraphical sequence and, therefore, Pre-Cambrian in age. To Professor Gee's argument, Professor Sahni replied in 1947: "Enough has been said to show that the field criteria upon which reliance is placed by the geologists of the Cambrian School are not safe criteria. The Salt Range question which has so long baffled us is no longer a problem of local significance. we must learn to judge it by standards based upon wider experience .. Between the testimony of the rocks and the testimony of the fossils, there can be no real conflict. When the two do not seem to agree, it is the direct evidence of the fossils that is to be relied upon· palaeontology is a surer foundation for stratigraphy than field evidence."

10. WORK DONE ON THE ASSAM TERTIARIES

Professor Sahni did much research on the micro-flora of the Assam Tertiaries undertaken on behalf of the Burmah Oil Company His research proved that the application of palaeobotanical methods had definite possibilities in the economic geology of Assam. In the later years of his life,

he became particularly interested in micro-palaeontology regarding which he says: "The last few decades have seen the rise of micro-palaeontology to a position of considerable importance in geology, particularly in the quest of oil."

He initiated research in India on fossil spores and pollen grains, called Palynology, and his interest in spores centred largely on using them for solving the problems of Indian Stratigraphy. The data on micro-fossils helped considerably in the classification of the geographical relations of the so-called unfossiliferous formations in India which were of an unknown or of a disputed age. He proved by his research that the Tertiaries of Assam are extremely rich in micro-fossils. He was very keen to build up a representative collection of spores and pollen of the modern Indian flora which could be used for comparison with the fossil forms, and had suggested a systematic study of the spores and cuticles in coals for correlating coal seams in India. The importance attached by him to palynological studies, i.e., the study of pollen grains and spores, is borne out by the opening of departments of palynology, coal-palaeobotany and oil-micropalaeontology at the Birbal Sahni Institute of Palaeobotany at Lucknow and at the Oil and Natural Gas Commission, Dehra Dun.

11. SAHNI'S CONTRIBUTIONS TO GEOLOGY

In 1893, H. W. Williams had coined the term Geochronology to describe studies in which the geological time-scale is applied to the earth and its inhabitants. He and Charles Schuchert, a well-known geologist of America, both maintained that the comprehensive meaning of the word geochronology meant the age of the earth on the basis of sediments and life. Frederick Zeuner, Professor

of Environmental Archaeology, University of London, summing up the subject, writes: "Both Williams' and Schuchert's definitions emphasize the close relationship between geochronology and stratigraphy, and the stratigraphy of terrestrial sediments is in no small measure based on palaeobotany. Birbal Sahni was right, because, in emphasizing that indirectly, and to a smaller extent directly, palaeobotany is destined to be one of the major factors in the further development of geochronology."

The study of fossil plants had suffered a great setback because the Indian geologists were sceptical of their value in geological chronology. In 1920, Professors Seward and Sahni published their volume on the revision of Indian Gondwana plants and it turned out to be a landmark in the history of Indian Geology and Palaeobotany. Professor Seward paid a great compliment to Professor Sahni by declining to undertake the study of certain fossil collections from India, sent to him by the Geological Survey of India, as he considered Birbal Sahni the right person to do so, by saying that his pupil had the first right to study them.

With Professor Sahni's return to India, Palaeobotanical research was revived. Being both a botanist and a geologist, he was the right man to initiate this revival. At a very early stage in his scientific career, he realised the great worth of geology in palaeobotanical research and finally convinced the geologists that the study of fossil botany yielded results of a far-reaching nature, results which the geologists could not afford to ignore.

Professor Sahni initiated the scrutiny of plant-bearing rocks of India by every conceivable technique that was known to the palaeobotanist. He was known for investigating the most controversial and unpromising sediments without prejudice. He not only improved the known

methods of investigation but also gave new methods particularly for investigating sediments considered earlier as unworthy of attention. He was known for his love of field work and, therefore, his activities were not merely confined to the laboratory. He missed no opportunity to visit fossil localities. His numerous visits to the Salt Range of Khewra, Rajmahal Hills of Bihar and the Deccan Intertrappean plateau were well known. At the fossil sites, he was a familiar figure armed with his note-book, his palaeobotanist's hammer and his camera. He had a very keen and shrewd perception and an understanding of complicated geological structures. All this is borne out by the voluminous notes that he has left behind. These notes cover various aspects of fossil botany, particularly on the Salt Range.

The Geological Survey of India has honoured him by erecting a bust of his at its Headquarters at Calcutta.

X

Savitri Sahni

THE biographical notes on Professor Birbal Sahni would be incomplete without a reference to his wife, Mrs Savitri Sahni, whom he married in 1922. She is the daughter of a friend of his father, Shri Sundar Das Suri, Inspector of Schools, Lahore, at that time. Later he retired as Principal of the Central Training College, Lahore.

Almost from the day that Birbal Sahni married Savitri Suri, he used to present her daily with two flowers. This had become a ritual and Mrs Savitri Sahni looked forward to this gift of two flowers to her by her husband. Not for a moment did she think that this ritual would stop one day. And then, suddenly, before she even realised the implication of it, death laid its cruel hand on Professor Sahni and her dream was shattered. The end came. Professor Sahni was no more and with that his gift of two flowers to her in the morning stopped. But according to Mrs Sahni, she still gets a gift of two flowers from him. When after her morning prayers, she puts flowers before the photograph of her husband, two flowers, and only two flowers, fall down at her feet. This, she considers, is a gift from him.

The close relationship that Professor Sahni and Mrs Sahni had and the mutual respect for each other had almost become a legend even during Professor Sahni's life time. "What a perfect, handsome couple they make," was a common remark. And there was a reason for that too.

Not many couples are as devoted to each other as they were. On *Karva chauth*, the fourth day of the waning moon in the month of Kartika (October-November), according to the lunar calendar, women from North India keep a strict fast for the long life, health and happiness of their husbands. It was not surprising that Mrs Sahni also kept this fast but what surprised many was that Professor Sahni also kept the fast along with her to reciprocate the feelings of his wife.

To Mrs Sahni, her husband was almost an institution and she lived only for him and his achievements. This admiration of hers for her husband was fully reciprocated and he in turn had full faith in her and discussed all his plans as well as his research findings and projects with her. She had not only attended his lectures as an undergraduate student, but had made him a subject of study. For her, he had become almost a religion, to the extent that from his routine of the day, she knew exactly what his mood would be in the evening and she would dress up to complement his mood. There never was an instant when he was irritable with her or lost his temper with her. In fact, his understanding of her wishes was fantastic and no matter how unreasonable, he always complied with them. This is clear from the following incident.

Professor and Mrs Sahni had themselves designed the house they built in Lucknow, on the banks of the river Gomati. When the house was under construction, often Mrs Sahni would change the plans. She would want a window here and a door there, or a wall pulled down. There was no question of Professor Sahni objecting to that and irrespective of the expense involved, the change would be made. This house was the pride of both of them and the last many years of their life were spent there. They were planning to build a barge so that Mrs Sahni could

go at the day's end to the Lucknow University, also situated on the banks of the river Gomati and not far from their residence, so that she could receive Professor Sahni at the end of the day at the university. But unfortunately this wish remained unfulfilled. Similarly, another wish which was also never to bear fruit was Professor Sahni's plans of converting his palatial residence at Almorah in the Kumaon Hills, into a residential summer headquarters for the Institute of Palaeobotany to shift to, during the unbearable hot summer days of the Indian plains. By shifting the laboratories to Almorah, he hoped the research work would go on unabated in the cool hills. But this was not to be.

When Birbal Sahni returned to India from Cambridge and joined the Benaras Hindu University, his mother thought that it was time Birbal got married and asked him about his wishes on the subject. He answered that whomsoever he married had to be an exceptionally beautiful woman and left the choice of the woman to his mother. Young Birbal's love for beauty in all forms of life was well known. His mother did not have to look far for a prospective daughter-in-law. Savitri, the daughter of Shri Sundar Das Suri, was known to her from her childhood days. Shrimati Iswar Devi made a hurried trip to Benares to apprise her son of the girl. Birbal Sahni, as was the custom of those days, relied on his mother's discrimination and agreed to marry Savitri Suri. He was not to be disappointed. He was so enamoured of her beauty that whenever he travelled with her, which was always in a first class railway coupe, as air travel was not the fashion in the early years of the century, he would always draw the curtains of the compartment whenever the train would steam into the stations en route. This was done to prevent eyes from straying into the compartment to gaze at his beautiful wife.

Mrs Savitri Sahni in turn reciprocated his warm feelings for her by doing only what pleased him. One such episode took place only a day before his fatal illness. Mrs Sahni was dressed in a light blue saree. Although it was an old saree, Professor Sahni, as if he had noticed it for the first time, remarked that the colour suited her very well. Promptly Mrs Sahni answered that in future he would see her only in that colour. But fate had ordained differently. The very next day, Professor Sahni had a severe heart attack from which he was not to recover and she was destined to wear widow's weeds for the rest of her life.

The understanding, sympathy and companionship that Mrs Sahni gave to Professor Sahni meant everything to him. The interest that she took in his scientific achievements and her unflinching devotion to him were fully appreciated by him. She always accompanied him on his scientific excursions both in India and abroad. He knew that if there was anyone he could depend upon, it was she. The encouragement, help and support that he received from her was often acknowledged by him His last words, seconds before he breathed his last, addressed to her, "Nourish the Institute", only confirmed his confidence in her. And it goes to her credit that she has served the cause for which her husband had worked with unflinching zeal; and one can say with full confidence that the Institute, what it is today, owes a lot to her efforts. But for her, the Institute might have died in its very infancy.

IX

In Conclusion

FEELING the need of a journal where scientific investigations in the field of Palaeobotany could be published, Professor Sahni was planning to start a journal, *The Palaeobotanist*. It is a paradox of fate that the first volume of the journal, which appeared in 1952, had to be the memorial volume to Professor Birbal Sahni. The Journal, the first of its kind, has a wide international scope and research papers appear in it from all corners of the world.

Birbal Sahni's was a personality full of physical and mental vigour. He was ever alert and never spared himself. Even a few weeks before his death, he had led an excursion to the Rajmahal Hills. There were several projects of research in his mind for the Institute of Palaeobotany, and among them was the mapping of the plant beds of India. Another project which was placed in high priority was to carry out expeditions to the various corners of India including the Spiti region of the Himalayas At the time of his death, he was engaged in a study of some Devonian plant fossils from Spiti and some of the Palaeozoic tree-ferns like *Tubicaulis*, *Ankyropteris*, *Psaronius* and some of the Deccan Intertrappean fossils like *Cyclantdodendron Sahnii*, *Sausarospermum Fermori* and *Nipadite* species.

Professor Sahni served the cause of Indian Science as few have done. He was associated with practically every important learned body, in his short span of fifty-seven years. So much was packed into his busy schedule that it

will be difficult to match another such personality. His achievements, condensed in a nutshell, are

After completing his studies at Lahore, first at the Central Model School and then at Government College, from where he obtained the degree of Bachelor of Science in 1911, he joined the Emmanuel College, Cambridge, for post-graduate studies. He obtained a First Class in Part I of the Natural Sciences Tripos in 1913, and was subsequently elected to a Foundation Scholarship in his college, and afterwards to a Research Studentship. In 1919, he returned to India after receiving a doctoral degree from the London University. By then his fame as a scientist had already spread far and wide and learned societies and institutions the world over vied with one another in honouring him.

In 1921, he was the President of the Lahore Philosophical Society. In 1924, he became the Founder-Member of the Indian Botanical Society and was its President more than once. In 1926, he presided over the Geological Section of the Indian Science Congress. In 1930, he was appointed Vice-President of the Palaeobotany Section of the fifth International Botanical Congress held at Cambridge which at that time was a rare distinction for an Indian.

In 1935, he was Vice-President of the Palaeobotany Section at the sixth International Botanical Congress held at Amsterdam and a year later, i.e., in 1936, he was honoured by the Royal Society of London by making him a Fellow. He was the fifth Indian and first Indian Botanist to become a Fellow of the Royal Society of London.

In 1932, he became a member of the Andhra University Commission, Board of Studies, Appointment Board, etc. He was awarded the highest honour that the Andhra

University bestows, the Cuttamanchi Ramalinga Reddy National Prize. In 1947, he delivered at this university the Alladi Krishnaswamy Memorial Lectures. In 1932, he was also appointed a Special University Lecturer at Lahore and again in 1936, an Extension Lecturer at Lahore and at Rohtak. Professor Sahni was twice President of the Botany Section of the Indian Science Congress, i.e., in 1921 and in 1938, which latter also happened to be the year of the Silver Jubilee Session of the Indian Science Congress Association. In 1936, Sahni was awarded the Barclay Medal for Biological Research and the C.R Reddy National Prize for Natural Sciences. He was the Subhraj Rai Reader in Natural Sciences, Patna University, in 1937; in 1938, the Adharchandra Lecturer in Natural Sciences, Calcutta University, and in 1944-45, the Gaekwad Lecturer, Baroda.

He became President of the National Academy of Sciences, India, in 1937-38 and again in 1942-44. In 1935, he was the Vice-President of the Foreign Section and in 1936 of the National Institute of Sciences, India. In 1940 he was the General President at the Madras Session of the Indian Science Congress Association. He was a member of the Scientific Manpower Committee and of the Scientific Consultative Committee, Government of India

Before joining Lucknow University, he was Professor of Botany at the Benares Hindu University for one year, from 1919 to 1920, and at Lahore in 1920-21.

In 1946, Professor Birbal Sahni went as a non-official member of the Indian delegation to the Royal Society Scientific Conference, London. He received the honorary degree of D.Sc. from the Patna University, and that of the Allahabad University in 1947.

In 1945, he was awarded the Nelson Wright Medal of the Numismatic Society for his find of the coin moulds

at Khokra Kot mound at Rohtak, and for his paper on Indian Numismatics, "Technique of casting coins in Ancient India."

He was the Foreign correspondent-member, Botanical Society of America, 1947, the Foreign Honorary Member, American Academy of Arts and Sciences, Boston, 1948; the official delegate of the Government of India to the 18th International Geological Congress, London, 1948. He was elected Honorary President of the International Botanical Congress, Stockholm, 1950, but was not destined to fulfil that commitment.

He was Editor of the Lucknow University Studies, Faculty of Science and of Palaeobotany in India, a Bulletin of Current Research, Lucknow.

After India gained independence in 1947, Maulana Abul Kalam Azad, the then Minister of Education to the Government of India, offered Professor Sahni the post of Secretary to the Ministry of Education. Professor Sahni was always a research worker, but he reluctantly agreed to accept the post. After the telegram of acceptance was sent to Delhi, he felt very unhappy and uncomfortable at the thought that he would be leaving his beloved laboratories for a mere clerical job. By then, it was midnight and after pacing the room for over an hour, he woke up Mrs Sahni and confided his doubts to her regarding the new post. Mrs Sahni, who was always consulted by him on all major and minor issues, agreed that he should decline the offer, and Professor Sahni went to the telegraph office at midnight and sent a second telegram rejecting the post with a request that since he had dedicated his life to research and to the work of setting up the Institute, he should not be asked to leave it for any other work. Not many in his place would have rejected such an offer.

Professor Sahni had an amiable striking personality and

his intellectual generosity made him share the gifts of his knowledge with all those who cared to learn. His intellectual honesty and objective approach to scientific truths had become a by-word. If his conclusions or observations regarding any research item were found to be in doubt, he was ever ready to be corrected and never stood on false prestige. He was emphatic regarding his views on controversial matters, but was never dogmatic. His graceful humour, bereft of sarcasm and cynicism, was one of his finest qualities. It was his habit to tell his personal view-point without any bitterness or rancour even when he knew that others disagreed with him, that won him universal esteem.

Professor Suzanne Leclerc of the University of Liege, paid him the following tribute "Professor Sahni's manners were exquisitely courteous, his brilliant intellect, his uprightness, the deeply human touch in his character awoke sympathy, which spontaneously rose to friendship. Among his merits was a vivid sense of duty, coupled with simplicity and modesty which is the character of true gentlemen."

Professor Sahni was a man of strict principles. He possessed a ready wit and enjoyed a joke even at his own expense.

He was always neatly and smartly dressed in white khadi *churidar* pajamas, a white *Sherwani* and a Gandhi cap. His graceful and polished manners always impressed all those who came in contact with him. He was a man of profound learning coupled with a charming personality. Combined with that was his eloquence of speech. He was a gifted orator. He had a cheerful disposition, calm, just, gentle and modest. The highest award in Botany is the Birbal Sahni Gold Medal for the best botanist of the year. The award was instituted by an ex-student of his, Professor T.S. Sadasivan, Plant Pathologist, Director of

the University Botany Laboratory, Madras. In an obituary tribute, he wrote: "A celebrated botanist has passed away in the wake of national exuberance and I firmly believe that posterity will class Professor Sahni with Engler, Strasburgor, Goebel, Sachs and de Bary of Germany, Guillermond of France and Scott, Seward and Bower of the United Kingdom, for his outlook like these men of science was truly rational, national and international. Verily, Professor Sahni has left 'foot prints' not 'on sands of time', but on the geological time-scale."

The amount of research work that Professor Sahni did in his life-time was so much that it is not possible to include all of it in this monograph. Suffice it to say that there is no aspect of fossil botany where Professor Birbal Sahni did not prove a success.

Appendix 1

Recipients of the Birbal Sahni Award

Year of Award	*Name*	*Address*	*Specialization*
1	*2*	*3*	*4*
1957	The late Prof. M. O. P. Iyengar	Professor & Director of Univ. Laboratory, Madras.	Algology.
1958	The late Prof. P. Maheshwari	Prof. & Head, Botany Deptt. Delhi Univ., Delhi.	Morphology, Embryology, Experimental Embryology.
1959	Prof. P. Parija	Ex-Vice-Chancellor, Utkal Univ., Cuttack, Orissa.	Plant Physiology.
1960	Dr E.K. Janki-Ammal	Emeritus Scientist, Centre for Advanced Studies in Bot., Univ of Madras.	Cytogenetics, Plant Geography, Ethenobotany.
1961	Dr B.P. Pal	Retired Director-General, I.C.A R.	Genetics, Plant Breeding.
1962	Prof. T.S. Sadasivan	Professor Emeritus, Centre for Advanced Studies in Botany, Univ. of Madras.	Plant Pathology.
1963	The late Prof J. Santapau	Director of Botanical Survey of India, Calcutta.	Plant Taxonomy.

1964	Prof. V. Puri	Prof. Emeritus, Deptt. Botany, Meerut University	Morphology, Morphogenesis' Embryology.
1965	Dr M.S. Swaminathan	Director-General, I C.A R	Genetics, Plant Breeding.
1966	Prof R.D. Misra	Retd. Prof. of Botany, Varanasi	Ecology, Physiology.
1967	The late Prof. R.K. Saxena	Prof. & Head, Dept. Botany, Univ. of Allahabad.	Mycology, Plant Pathology.
1968	Prof. P.N. Mehra	Prof of Botany, Punjab Univ., Chandigarh	Cytogenetics, Morphogenesis, Bryophyta, Pteridophyta.
1969	Prof S M Sircar	Retd. Prof , Bose Institute, Calcutta.	Plant Physiology, Biochemistry
1970	Prof B M. Johri	Head & Prof of Botany, Univ. of Delhi.	Morphology, Embryology Morphogenesis, Exp. Embryology.
1971	Prof. J. Venkateshwarlu	Prof Emeritus, Dept. Botany, Andhra Univ., Waltair	Embryology, Genetics, Morphology, Cytogenetics, Taxonomy.
1972	Prof. C.V. Subramanian	Prof. Univ Botany Laboratory, Madras.	Mycology, Plant Pathology.
1973	Prof. R P. Roy	Prof. & Head, Dept. Botany, Patna Univ , Patna	Cytogenetics, Plant Breeding.

1	*2*	*3*	*4*
1974	Prof. A K Sharma	Prof. & Head, Botany Dept , Calcutta Univ., Calcutta.	Cytogenetics, Cell Biology, Cytochemistry.
1975	Prof. B.G L. Swamy	Prof. of Botany, Presidency College, Madras.	Morphology, Anatomy, Embryology.
1976	Prof. D.D Pant	Head, Dept. of Botany, Allahabad Univ., Allahabad.	Palaeobotany, Morphology, Anatomy of Vascular Plants.
1977	Prof. K K. Nanda	Prof. Dept. Botany, Panjab Univ , Chandigarh	Plant Physiology, Biochemistry, Morphogenesis.

to be awarded in Jan. 1978

Appendix 2

Geological Time-scale

System	*Evolution*
	(0)[1]
HOLOCENE PLEISTOCENE (1)[2]	Widespread glaciation. Mountains reach present heights. Mammals die off in cold Man appears. Modern fauna and flora in Holocene.
	(1)
PLIOCENE MIOCENE (25)	Marine sediments heaved into Himalayan-Alpine mountain. Flora becoming temperate Grazing types evolve as grasslands spread. Change of man-ape to man in Pliocene.
	(26)
OLIGOCENE EOCENE (35)	Himalayan alpine orogeny. Igneous activity. Palms. Carnivores, rodents, early horses, elephants, lemurs Dawn of modern life Monkeys, apes in Oligocene. Climax of mummulites.
	(61)
CRETACEOUS (70)	Maximum spread of sea. Flowering plants, deciduous trees. Dinosaurs, toothed birds reach climax, die out. Ancestors of marsupials, placental mammals.

[1]Age in million years.
[2]Duration in million years.

JURASSIC (40)	Hills, swampy lakes, meanders. Temperate climate. Luxuriant vegetation. Division of southern hemisphere. Flying insects. Termites, snails, frogs. Toothed birds.	(131)
TRIASSIC (30)	Deserts, scree-covered mountains, deltafans. Tethyan sea dividing two hemispheres Conifers, cycads dominate. Dinosaurs. First mammals. Ammonites evolve.	(171)
PERMIAN (25)	Continental uplift and orogeny. Salt deposition in lagoons. Climatic extremes. Evolutions and extinctions. Mammalian reptiles. Conifers.	(201)
CARBONIFEROUS (55)	Warm humid climate. Coal formation. Scale trees, seed ferns in swamps. Reptiles. Shell-crushing sharks. Brachiopods, mollusca, bryzoa multiply.	(226)
DEVONIAN (55)	Erosion of mountains. Land partially vegetated, land and fresh water invertebrates. Wingless insects.	(281)
SILURIAN (35)	Deepening of seas. Climate equable. Widespread coral reefs. Plants develop adaptation for land life Mountain building.	(336)
ORDOVICIAN (80)	Spreading of seas Biochemical deposition. New invertebrate—graptolites.	(371)
CAMBRIAN (100)	Shallow seas encroach on land. First invertebrates with hard parts—trilobites, brachiopods.	(451)

		(551)
PRE-CAMBRIAN (949)	Landscape of mountains, deserts and volcanoes, condensation of water in earth wrinkles. Algal precipitations. Worm trails.	
		(1500)
ARCHAEAN (2500)	Solidification of earth. Bacterial iron and carbonaceous deposits suggest presence of life.	
		(4000)

Appendix 3

A List of Research Papers of Professor Birbal Sahni

1915. Foreign pollen in the ovules of *Ginkgo* and its significance in the study of fossil plants. *New Phytol.* **14** (4 and 5), 149-151.

1915. The anatomy of *Nephrolepis volubilis* J. Sim with remarks on the biology and morphology of the genus. *New Phytol.* **14** (8 and 9), 251-274.

1916. The vascular anatomy of the tubers of *Nephrolepis*. *New Phytol* **15** (3 and 4), 72-80.

1917. Observations on the evolution of branching in the Filicales. *New Phytol.* **16** (1 and 2), 1-23.

1918. On the branching of the Zygopteridean leaf and its relation to the probable 'pinna' nature of *Gyropteris sinuosa* Goeppert. *Ann. Bot.* **32** (127), 369-379.

1919. (With J. C. WILLIS.) *Lawson's text book of botany*. London: Univ. Tut. Press.

1919 On an Australian specimen of *Clepsydropsis*. *Ann. Bot.* **33** (129), 81-92.

1920. Petrified plant remains from the Queensland Mesozoic and Tertiary formations. *Queensland Geol. Surv. Publ.* No. 267, pp. 1-48

1920. On the structure and affinities of *Acmopyle Pancheri* Pilger. *Phil. Trans.* B, 210, 253-330.

1920. (With A. C. SEWARD.) Indian Gondwana plants: a revision. *Mem. Geol. Surv. Ind. Pal. Ind.* 7 (1), 1-40.

1920. On certain archaic features in the seed of *Taxus baccata*, with

remarks on the antiquity of the Texinea. *Ann Bot.* 34 (133), 117-133.

1921. On a new abnormality in the sporophyll of *Tmesipteris. Proc. (8th. Ind. Sci. Cong. Cal) Asiat. Soc. Beng.* (N.S) 17 (4), 179.

1921. A stem impression from the plant-bearing beds near Khunmu (Kashmir), Provisionally referred to *Gangamopteris Kashmirensis* Seward. *Proc (8th Ind. Sci. Cong. Cal.) Asiat Soc. Beng.* (N.S), 17 (4), 200.

1921. Note on the presence of a 'tent-pole' in the seed of *Cephalotaxus Pedunculata. Ann. Bot* 35 (138), 297-298.

1921. The present position of Indian Palaeobotany. Pres. Add. 8th Ind Sci. Cong. Cal. *Proc. Asiat Soc. Bengal* (N. S.), 17 (4), 152-175.

1923. On the theoretical significance of certain so-called 'abnormalities' in the sporongiophores of the Psilotaceae. *J. Ind Bot. Soc.* 3 (7), 185-191.

1923. Modern Psilotaceae and archaic terrestrial plants. *Nature,* 3, 84.

1923. On the structure of the cuticle of *Glossopteris angustifolia* Brongn *Rec. Geol. Surv. Ind* 54 (3), 277-280.

1924. On the anatomy of some petrified plants from the Government Museum, Madras. *Proc. 11th Ind. Sci. Cong. Bangalore,* p. 141.

1925. The antogeny of vascular plants and the theory of recapitulation. *J. Ind Bot. Soc.* 4 (6), 202-216.

1925. (With E. J. BRADSHAW.) A fossil tree in the Panchet Series of the Lower Gondwanas near Asansol. *Rec. Geol. Surv. Ind.* 58 (1), 77-79.

1925. On *Tmesipteris Vieillardi* Dangeard, an erect terrestrial species from New Caledonia. *Phil Trans* B, 213, 143-170.

1926. The southern fossil floras—A study in plant geography of the past. (Pres. Add.) *13th Ind. Sci. Cong. Bombay,* pp. 229-254.

1926. (With T.C.N. SINGH) On some specimens of *Dadoxylon Arberi* Seward from New South Wales & Queensland. *J. Ind. Bot. Soc* 5 (3), 103-112.

1927. (With A. K. MITRA.) Notes on the anatomy of some New Zealand species of *Dacrydium. Ann. Bot.* 41 (161), 75-89.

1927. On some petrified cones of Indian fossil conifers from the British Museum, London. *Proc. 14th Ind. Sci. Cong. Lahore,* p. 215.

1927. A note on the floating island and vegetation of Khajiar, near Chamba, in the N.-W. Himalayas. *J. Ind Bot Soc.* 6 (1), 1-7.

1928. Some petrified palms from the Central Museum, Nagpur. *Proc 15th Ind Sci. Cong. Calcutta*, p. 228.

1928. On a collection of petrified tree-trunks discovered in Eden Gardens, Calcutta. *Proc. 15th Ind. Sci Cong. Calcutta*, p. 228.

1928. Dicotyledonous plant remains from the Tertiary beds of Assam *Proc. 15th Ind. Sci. Cong. Calcutta*, p. 294.

1928. On *Clepsydropsis australis*, a Zygopterid tree-fern, with a *Tempskya*-like false stem, from the Carboniferous rocks of Australia. *Phil. Trans. B*, 217, 1-37.

1928. Revisions of Indian fossil plants Pt. I. Coniferales. (Impressions and incrustations.) *Mem., Geol. Surv. Ind.* (N S.), 11, 1-49.

1930. The relation of the late Palaeozoic floras to the early Mesozoic floras *Proc. 5th Int Bot Cong. Cambridge*. pp. 503-504.

1930. On *Asterochlaenopsis*, a new genus of Zygopterid tree-fern from Western Siberia. *Phil. Trans. B*, 218, 447-471.

1931. On certain fossil epiphytic ferns found on the stems of the Palaeozoic tree-fern *Psaronius Proc. 18th Ind. Sci. Cong. Nagpur*, p. 270.

1931. (With T.C.N. SINGH) Notes on the vegetative anatomy and female cones of *Fitzroya patagonica* (Hook Fils). *J. Ind. Bot. Soc.* 10 (1). 1-20.

1931. Materials for a monograph of Indian petrified palms. *Proc. Acad. Sci U.P.* 1, 140-144.

1931. Revisions of Indian fossil plants. Pt. II Coniferales (b. petrifactions). *Mem Geol Surv. Ind. Pal Ind* (N. S) 2, 51-124.

1931. Miscellaneous notes. Supplementary note on revisions of Indian fossil plants. Pt. II. Coniferales (b. petrifactions). *Rec. Geol Surv. Ind.* 65 (3), 441-442.

1932. *Palmoxylon Mathuri*, a new species of petrified palms from Cutch, Western India. *Proc. 18th Ind. Sci. Cong. Bangalore*, p. 322.

1932. Anatomical proof of the cycadophyte affinities of *Taeniopteris spatulata* McCl. *Proc 18th Ind. Sci. Cong. Bangalore*, p. 322.

1932. On the Genera *Clepsydropsis* and *Cladoxylon* of Unger, and on a new genus *Austroclepsis*. *New Phytol.* 31 (4), 270-278.

1932. On the structure of *Zygopteris*, primacia (Cotta) and on the

relations between the genera Zygopteris, *Etapteris* and *Botrychioxylon*. *Phil. Trans. B*, 222, 29-45.

1932. *Homozylon rajmahalense* gen. et. sp. nov., a fossil angiospermous wood, devoid of vessels, from the Rajmahal Hills, Bihar. *Mem. Geol. Surv. Ind. Pal, Ind.* **20** (2), 1-19.

1932. A petrified *Williamsonia* (*W. Sewardiana*, sp. nov.) from the Rajmahal Hills, India. *Mem. Geol. Surv. Ind. Pal. Ind.* **20** (3), 1-19.

1932. On a palaeozoic tree-fern, *Grammatopteris Baldaufi* (Beck) Hirmer, a link between the *Zygopteridеae* and *Osmundaceae*. *Ann. Bot.* **46** (184), 863-877.

1932. Staminal movements in *Gerbera lanuginosa*. *J. Ind. Bot. Soc.* **11** (3), 241-242.

1933. The wood anatomy of a homoxylous dicotyledon, *Tetracentron sinese* Oliv. *Proc 20th Ind. Sci. Cong. Patna*, p. 317.

1933. (With A R. RAO) On some Jurassic plants from the Rajmahal Hills. *Asiat Soc. Bengal* (N. S.), **27** (2), 183-208.

1933. *Dadoxylon Zalesskii*, a new species of Cordaitales trees from the Lower Gondwanas of India. *Rec. Geol. Surv. Ind* **66** (4), 414-429.

1933. A fossil pentalocular fruit from Pondicherry, South India. *Rec. Gael. Surv Ind.* **66** (4), 430-437.

1933. On some abnormal leaves of *Ginkgo*. *J. Ind Bot. Soc.* **12** (1), 50-55.

1933. Explosive fruits in *Viscum japonicum* Thunb *J. Ind. Bot Soc.* **12** (2), 96-101.

1934. The silicified flora of the Deccan Intertrappean Series, Pt. I. General. *Proc 21st Ind. Sci. Cong. Bombay*, 316-317.

1934. The silicified flora of the Deccan Intertrappean Series, Pt. II. Gymnospermous and angiospermous fruit. *Proc 21st Ind. Sci. Cong Bombay*, pp 317-318.

1934 (With B. P. SRIVASTAVA.) The silicified flora of the Deccan Intertrappean Series. Pt III. *Sausarospermum Fermori*. gen. et sp nov. *Proc. 21st Ind. Sci. Cong. Bombay*, p. 318.

1934 Dr. S K. Mukerji, F. L. S. (1896-1934) (Obituary.) *J Ind. Bot Soc.* **13** (3), 245-249.

1934 (With A. R. RAO) *Rajmahalia paradoxa* gen. et sp. nov. and other Jurassic plants from the Rajmahal Hill. *Proc. Ind. Acad. Sci* **1**, (6) 258-269.

1934. Dr. Dukinfied Henry Scott. (Obituary.) *Curr. Sci.* 2 (10), 392-395.
1934. The Deccan Traps: Are they Cretaceous or Tertiary? *Curr. Sci.* 3 (10), 392-395.
1935. The relations of the Indian Gondwana flora with those of Siberia and China. Proc. *2nd Cong of Carb Stratig. Heerlen Holland Compte Rendu* 1, 517-518.
1935. The Glossopteris flora in India *Proc 6th Int. Bot. Cong Amsterdam*, 2, 245-248.
1935. *Homoxylon* and related woods and the origin of angiosperms. *Proc. 6th Int. Bot. Cong. Amsterdam* 2, 237-238.
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